Oklahoma Geological Survey

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FIELD TRIP GUIDE TO THE TAR CREEK SUPERFUND SITE PICHER, OKLAHOMA

Chat Pile in Picher, Oklahoma

OKLAHOMA SECTION
AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
ANNUAL STATE MEETING
April 28-29, 2006
Shangri La Resort
Grand Lake, Oklahoma

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Keheley & Associates, Inc.

Tri-State Mining District/Picher Field Timelines

Ore deposits near Joplin discovered about 1848.

Southwestern Missouri became one of the early battlegrounds during the Civil War.

1890's-early 1900's, Peoria, Quapaw, Lincolnville, and Commerce mining camps open.

In 1914, Picher Lead Co. announced discovery of a rich ore deposit on the Crawfish Lease, near what is now Picher, Oklahoma.

1920-1929, the golden years of the district.

Mid 1920's, general adoption of flotation process by mills in the Picher Field.

1926, about 143 mills were in operation in the district.

1930, the first central mill, Bird Dog mill, was completed; 2,700 tons/day.

Early 1930s, large-capacity sump pumps were pumping more than 13 million gal/day to maintain unsaturated conditions in the mine workings.

1932, Eagle-Picher completes a central mill; initial capacity 3,600 tons/day; stepped up to 5,500 tons/day.

1940-1949, many ups and downs, with the mining industry being subjected to the governmental controls associated with Word War II.

1950-1959, marked the end of the major mining activities within the Tri-State District.

1970, the last record of significant production.

November 1979, acid-mine water began discharging from an abandoned drill hole near Commerce.

Early 1980, Governor of Oklahoma, George Nigh, formed a the Tar Creek Task Force, composed of 24 local, state, and federal agencies, to investigate the effects of acid mine drainage on the areas's surface and ground water supplies.

July 1981, EPA proposes to add the Site to the Superfund National Priorities List (NPL).

On September 8, 1983 the Site was listed on the NPL.

1984-1986, dikes were built to divert surface water around collapsed mine shafts and 88 abandoned Roubidoux wells were plugged (OU1).

1995, EPA begins yard remediation activities in the five-city mining area in response to elevated blood-lead levels in children (OU2).

2000, EPA disposed of 120 deteriorating containers of lead recovering chemicals at Eagle-Picher Industries mining laboratory in Cardin.

January 26, 2000 Governor Frank Keating creates a task force to develop a comprehensive remediation plan for Tar Creek.

2003, Oklahoma plan is developed for stream restoration, maximum chat utilization, land remediation and restoration, and mine-hazard attenuation.

2003, MOU signed by EPA, DOI, and U.S. Army Corps of Engineers

2003, the Oklahoma Conservation Commission (OCC) completes a 54-acre land reclamation and restoration pilot project at McNeely Site.

2004, U.S. Army Corps of Engineers completes assessment of the Tar Creek and Spring River Watersheds.

2004, EPA initiates a chat disposal pilot project; OCC begins land restoration project near Commerce.

2004, Lead Impacted Communities Relocation Trust was formed to move children 6 years old and younger away from the Picher-Cardin area.

2006, Report to evaluate the potential for future subsidence in the Tar Creek Superfund Site in key transportation corridors and population centers was released.

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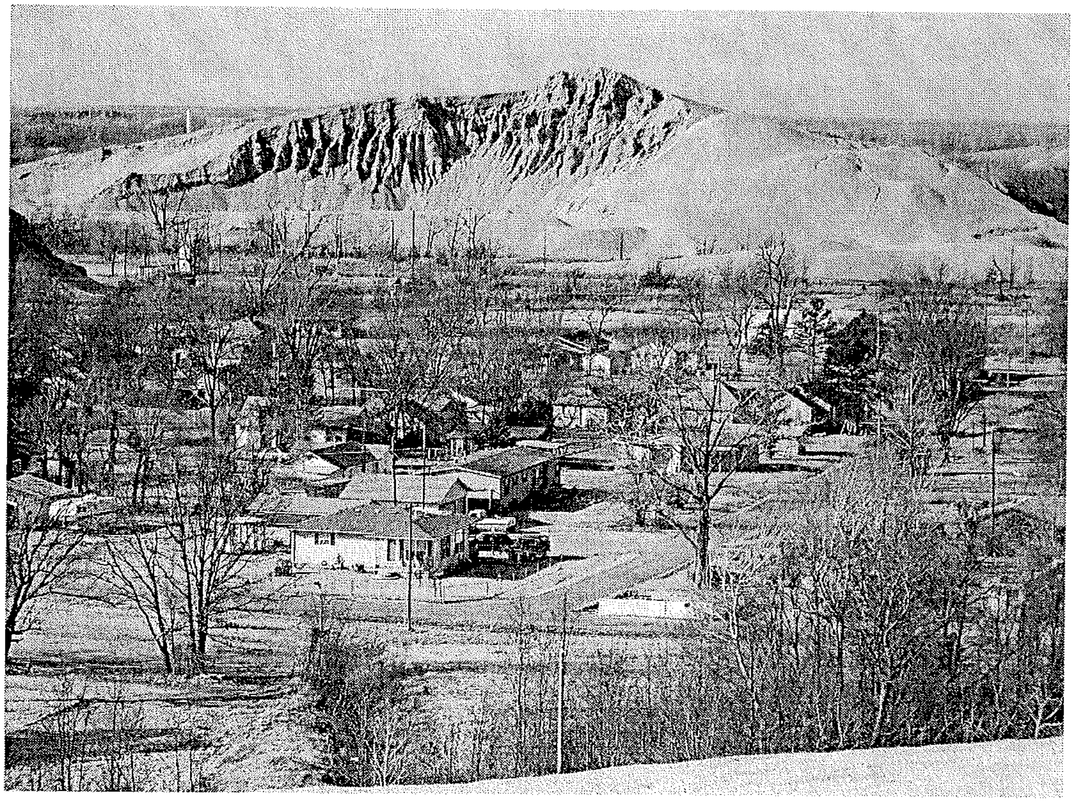

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2006

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COVER PHOTO: Chat pile on the St. Joe Mine west of the Old Little League Ball Park and Ray Harrell City Park, Picher, Oklahoma

FIELD TRIP GUIDE TO THE TAR CREEK SUPERFUND SITE PICHER, OKLAHOMA

Kenneth V. Luza[1] and W. Ed Keheley[2]

ABSTRACT

The Tar Creek Superfund Site is located in northeastern Oklahoma near the Oklahoma/Kansas border in Ottawa County. The site consists of approximately 41 square miles (26,000 acres) and is part of the Tri-State Mining District (OK, KS, and MO). The Mississippian rock units, principally the Boone Formation, are the host for most of the ore deposits. Zinc and lead ores (principally sphalerite and galena) were mined in the Picher Field in northeastern Oklahoma and southeastern Kansas for more than 60 years. The Superfund site contains over 2,500 acres that are underlain by underground lead-zinc mines and 1,190 mine shafts. Significant quantities of mill-waste material were generated by milling of the lead-zinc ores. Approximately 5,000 acres in Oklahoma were overlain by mine and/or mill byproducts. The field trip will visit mine and mill-waste sites, locations where ongoing ground failure is occurring, sites where mine water is discharging from mine shafts and boreholes, and a plant where chat is reprocessed for asphalt aggregate. The many challenges and issues associated with the Tar Creek Superfund Site are discussed during the field trip.

INTRODUCTION

Zinc and lead ores (principally sphalerite and galena) were mined in the Picher Field in northeastern Ottawa County, Oklahoma and southeastern Cherokee County, Kansas for more than 60 years. The Picher Field was part of the Tri-State Mining District, Missouri, Kansas, Oklahoma (Fig. 1).

The eastern part of the Oklahoma portion of the Picher Mining Field (the Peoria Camp) is situated on the west edge of the Ozark Plateau province. The Ozark Plateau is a broad, low structural dome lying mainly in southern Missouri and northern Arkansas. However, the main part of the Picher Mining Field is within the Central Lowland province. A nearly flat, treeless prairie underlain by Pennsylvanian shales characterizes this province.

The streams that traverse the mining field flow southward to the Neosho River are slightly incised below prairie level. Elm Creek, on the west side, and Tar Creek and its main tributary, Lytle Creek, are the principal streams in the main productive part of the Picher Mining Field. Elm, Tar, and Lytle creeks furnished some water for the mills. However, most mill water was pumped from the mines and/or from deep wells. A short distance east of the Picher Mining Field is the Spring River, which is the major south-flowing tributary of the Neosho River. The physiographic boundary closely parallels the Spring River: the region east of the river is hilly, moderately dissected by through going streams; whereas to the west, the terrain is nearly level prairie.

Topographic relief in the mining field is relatively small. The lowest point, south of Commerce, is about 780 ft above mean sea level. From Commerce, the land rises gradually to an

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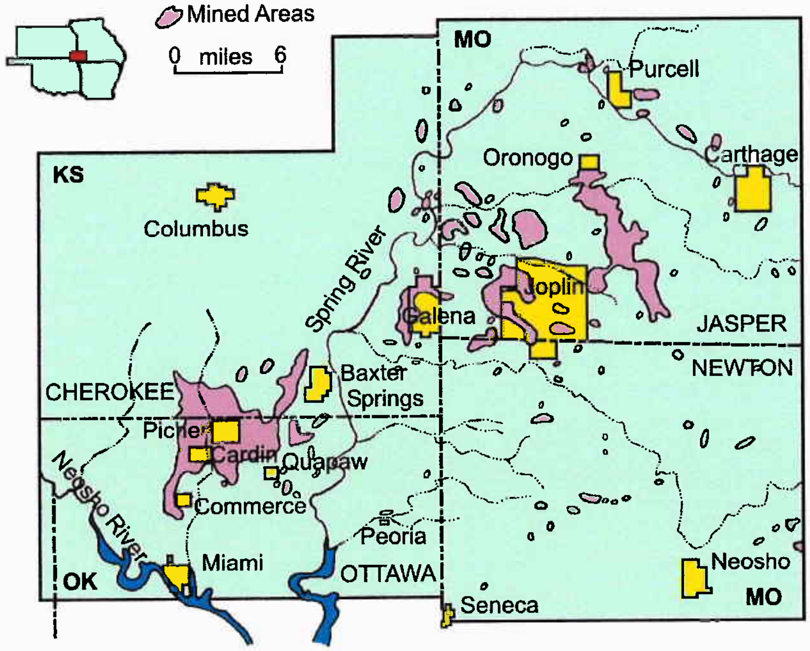

Fig. 1. Tri-State Mining District.

average altitude of 830 ft above mean sea level. In the eastern part of the field (Section 30, T29N, R24E), one summit is as high as 900 ft above mean sea level.

The normal annual precipitation at Miami, Oklahoma, about 7.5 miles southwest of Picher, Oklahoma, is 44.85 in.; but yearly totals have ranged from 19.89 in. (1963) to 66.9 in. (1973) (Oklahoma Climatological Survey). The heaviest precipitation comes during the spring, but September and October are also wet. Winter is the driest season. January, the driest month, has an average annual precipitation of 1.65 in. (based on the 1971–2000 average).

The mean annual temperature at Miami is 57.6°F (based on the 1971–2000 average). July is the hottest month, and January the coldest. The highest temperature recorded in Miami was 116°F on July 14, 1954; the lowest temperature recorded in Miami was –25°F on January 22, 1930 (Oklahoma Climatological Survey). The average growing season, from the last killing frost in the spring to the first in the fall, is 200 days. Average annual snowfall in Miami is 10 inches. Snowstorms are usually of short duration, and the snow remains on the ground only a few days.

U.S. Environmental Protection Agency (EPA) proposed the Picher Mining Field known as the Tar Creek site be added to the National Priorities List (NPL). The NPL is a list compiled by EPA pursuant to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) section 105, 42 U.S.C. § 9605, of uncontrolled hazardous substance releases in the United States that are priorities for long-term remedial evaluation and response. This site was listed on the NPL on September 8, 1983 and became known as the Tar Creek Superfund Site.

REGIONAL GEOLOGY

The geologic framework and origin of the lead and zinc deposits have been discussed by numerous authors. These publications include Siebenthal (1908), Weidman and others (1932), Reed and others (1955), Brockie and others (1968), and McKnight and Fischer (1970). The Picher Mining Field straddles the Cherokee Platform–Ozark Plateau.

The rock formations exposed at the surface in the mining field include Mississippian and Pennsylvanian units that are nearly flat, with a low, regional northwestward dip of about 20–25 ft/mile (Fig. 2). Cambrian and Ordovician formations, primarily dolomite and chert with some sandstone and minor shale, are encountered only in deep drill holes and water wells in this area.

Mississippian rock units, principally the Boone Formation, are the host for most of the ore deposits. The Boone Formation is composed of fossiliferous limestone and thick beds of nodular chert (Fig. 3). The Boone Formation, which is 350–400 ft thick in the Picher area, is subdivided into seven members (in ascending order): St. Joe Limestone, Reeds Spring, Grand Falls Chert, Joplin, Short Creek Oolite, Baxter Springs, and Moccasin Bend (McKnight and Fisher, 1970). Fowler and Lyden (1932) and Fowler (1942) further subdivided these members into 16 beds. Letters of the alphabet were used to distinguish individual beds, beginning with *B* near the top of the Moccasin Bend member and ending with *R* in the Reeds Spring member (Fig. 4). In Oklahoma, the Boone Formation is not usually subdivided into these members.

The Quapaw Limestone near Lincolnville and in part of the main Picher Mining Field overlies the Boone Formation. The Chesterian Series, represented by the Hindsville Limestone, Batesville Sandstone, and Fayetteville Shale, generally forms a disconformable contact with the Boone Formation and/or Quapaw Limestone. Chesterian rocks are exposed on the east side of the Picher Mining Field. However, the Batesville and Hindsville also outcrop near Douthat (T29N, R23E, sec. 29). Both the Hindsville and Batesville are locally mineralized, especially in the eastern part of the mining field near Lincolnville.

Pennsylvanian formations of the Krebs Subgroup (lower division of the Cherokee Group) overlie the Boone Formation. The Krebs Subgroup was deposited on a post-Mississippian erosion surface. The formations, as mapped by Branson (Reed and others, 1955), include the McAlester Formation, the Savanna Formation, and the basal Bluejacket Sandstone Member of the Boggy Formation. These formations consist of alternating terrestrial fine-grained sandstone, shale, and thin coal beds. The sandstone units are discontinuous and vary significantly in thickness where they are laterally continuous.

Drillers' logs were used by mining company geologists to characterize the site geology on individual mine leases in the Picher Field. They grouped geologic formations that had similar lithologies and engineering properties into three categories. The Krebs Subgroup units, Fayetteville Shale, and Batesville Sandstone were grouped into a category called *shale or soapstone*. The first occurrence of limestone on a driller's log was called the top of the *Chester*. This category included the Hindsville and Quapaw Limestones. The first occurrence of flint and/or chert on a driller's log was used to determine the top of the Boone Formation.

Ore Deposits

The ore deposits in the Picher Mining Field occur mainly in the upper half of the Boone Formation. A majority of the mine workings are within the *M* bed. Other important ore zones occurred within the *K*, *G*, *H*, and *E* and Chesterian beds, and sheet ground, or low-grade blanket deposits, occurred within the Grand Falls Chert Member (generally corresponds to the *O* bed).

Nearly all the ore bodies in the Picher Mining Field are tabular masses whose horizontal dimensions exceed their thickness. Some ore bodies are blanket-like bodies, dominantly irregular or lobate in plan, but tended to be slightly elongated and curved. These bodies grade into others, called runs, which are flat, narrow, elongate, and usually curvilinear. Many of the runs tend to form closed but irregular-shaped circles around barren cores. Some runs are vertical and vary from 10 to 15 feet wide and over 100 feet high. Vertical runs have steeply inclined walls and generally follow near vertical fracture zones in the rocks. Some of the smaller ore bodies, called "pockets," have a somewhat circular shape. They are usually separated from the main ore body by slightly mineralized and/or barren rock. Many of the ore pockets occur in highly brecciated rock locally described as "boulder ground." Boulder ground is composed of 1–5 feet-angular, silicified and/or dolomitized blocks of fracture rock cemented by ore and gangue minerals (Weidman and others, 1932; McKnight and Fischer, 1970).

Most of the ore bodies are largely confined to a definite stratigraphic interval; so tops and bottoms of these are therefore, crudely parallel. Stopes in bodies of this type are commonly 10–20 ft high. Where two or more stratigraphic units contain ore bodies that are superimposed or partly overlap, they were mined together, and in such places stopes may be 50–100 ft high. If the ore-bearing units are separated by much waste rock, they were mined at separate levels (McKnight and Fischer, 1970).

The chert within the Boone Formation was structurally deformed and shattered prior to mineralization. Much of the ore is in the matrix of a chert breccia. The limestone that originally formed this matrix was either removed by leaching or was entirely replaced by the ore and gangue minerals. The ore consists of sphalerite, galena, dolomite, and jasperoid, with an unreplaced residuum of chert. Accessory metallic minerals are chalcopyrite, enargite, luzonite, marcasite, and pyrite. Considerable calcite and some quartz and barite occur in the ore. The zinc-to-lead ratio for the ore, based on the total production of the field, was about 4.1:1 (McKnight and Fischer, 1970).

Geologic Structure

At a few places, sharply defined structural features are accompanied by appreciable dips. The Miami Trough, Bendelari Monocline, and Rialto Basin are three prominent structures that dominate the main part of the Picher Mining Field (Fig. 2). The Miami Trough is a linear feature (syncline and/or graben) that crosses the western part of the Picher Mining Field with an average trend of N 26° E. The width of this structure is 300–2,000 ft, averaging about 1,000 ft. The maximum vertical displacement is about 300 ft. The Bendelari Monocline crosses the mining field with a northwest strike and drops the mineral-bearing ground a maximum of 140 ft on the northeast side. The maximum dip is about 20°. Chesterian strata are preserved in greater thicknesses on the down-dropped side, and the structure is hardly noticeable in Pennsylvanian strata. The Rialto Basin is an irregular, east-trending, faulted syncline nearly a mile long and as much as a quarter of a mile wide. It has a maximum displacement of 80 ft and contains a thicker sequence of Chesterian strata than normal (McKnight and Fischer, 1970).

The linear structural features, such as the Miami Trough, are of tectonic origin and probably have been modified by some dissolution of carbonate rocks at depth, resulting in additional subsidence. The Rialto Basin and smaller basins may have developed where dissolution along deep-seated fractures was accompanied by subsidence (McKnight and Fischer, 1970).

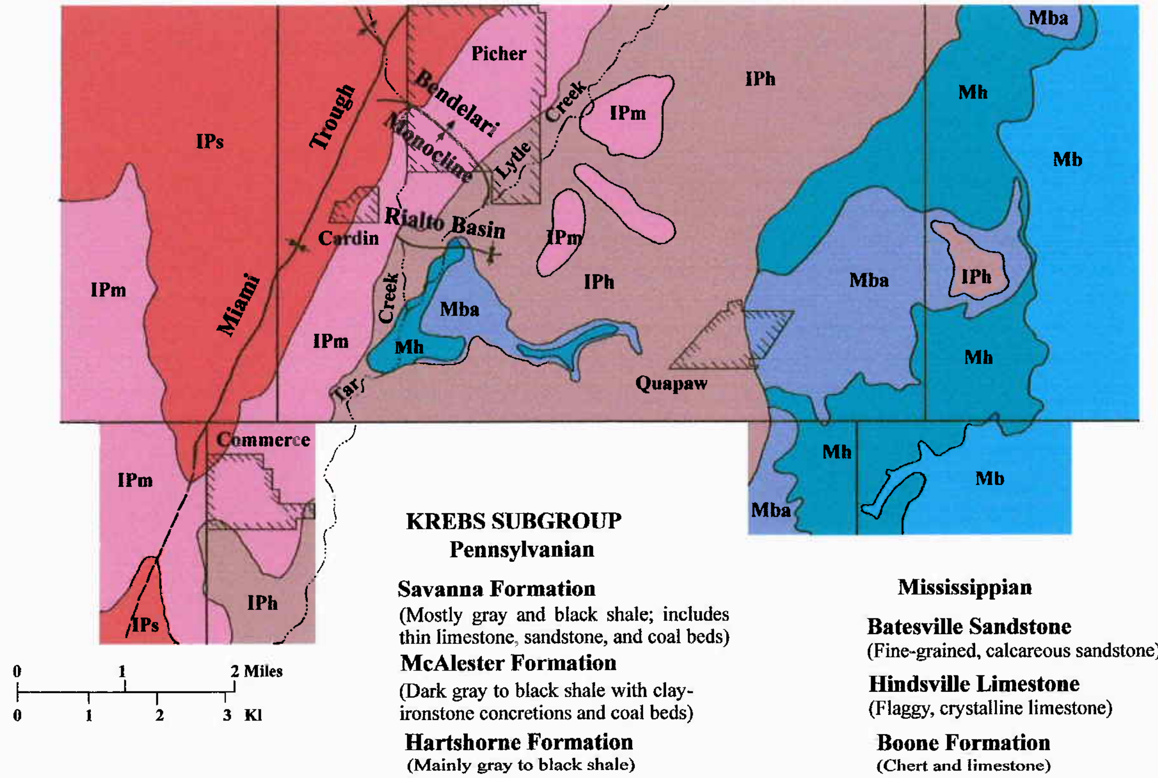

Fig. 2. Generalized geologic map, Picher Field, Oklahoma, with major structural features, Miami Trough, Bendelari Monocline, and Rialto Basin.

Fig 3. Interbedded limestone and chert in the upper part of the Boone Formation

System	Series	Group, Formation, or member		Bed
PENNSYLVANIAN	Desmoinesian	Krebs Subgroup (Cherokee Group)	Boggy Formation Bluejacket Sandstone Member	
			Savanna Formation Doneley Limestone Member (Reed and others, 1955)	
			McAlester Formation Warner Sandstone Member	
			Hartshorne Formation McCurtain Shale Member	
MISSISSIPPIAN	Chesterian	Fayetteville Shale		
		Batesville Sandstone		
		Hindsville Limestone		
	Meramecian	Quapaw Limestone		
		Boone Formation	Moccasin Bend Member	B C D *E* F *G* *H*
			Baxter Springs Member	J *K* L
			Short Creek Oolite Member	
	Osagean		Joplin Member	*M*
			Grand Falls Chert Member	N *O* P Q
			Reeds Spring Member	R
	Kinderhokian and Upper Devonian		St. Joe Limestone Member	
MISSISSIPPIAN and DEVONIAN		Chattanooga Group		
ORDOVICIAN	Lower Ordovician	Cotter Dolomite Jefferson City Dolomite Roubidoux Formation Gasconade Dolomite Gunter Sandstone		
CAMBRIAN	Upper Cambrian	Eminence Dolomite Potosi Dolomite Derby-Doe Run Dolomite Davis Formation Reagan Sandstone		
PRECAMBRIAN		Granite and volcanics		

Fig. 4. Correlation chart for the Tri-State District, Oklahoma, and important ore zones shown in red (modified from Luza, 1986).

Hydrology

Ground water is the primary source of water within the study area. Three primary aquifers are present within the study area. Two of the aquifers, the Boone and the Chat are shallow and the water is not potable. The recently identified Chat Aquifer, is an artificially created unconsolidated surficial aquifer composed of mine tailings distributed over much of the Picher Mining Field (Mark Becker, 2005, personal communication). Thicknesses range from just a few feet to several hundred feet where large piles still exist. Recharge over the Chat Aquifer is rapid due the relative textural homogeneity and unconsolidated nature of the material. Base flow in Tar and Lytle creeks are generally sustained through the mining area by discharge from this surficial deposit. However, most of the domestic, municipal, and industrial supply is from the deep Roubidoux aquifer.

The Roubidoux Aquifer underlies the Boone Aquifer and is generally a fractured cherty dolomite interbedded with thin sandstones. Uppermost portions of the Roubidoux Aquifer are less permeable, which therefore restricts vertical movement of water from the Boone into the Roubidoux Aquifer. Large municipal and industrial withdrawals have lowered the water levels in the Roubidoux from pre-pumping levels where wells were artesian to 300–500 feet below land surface. Roubidoux supply wells in the mining area are often drilled to a depth of 900–1,100 feet and are cased to the base of the Boone Aquifer. Water was withdrawn from the Roubidoux when the mining was active to supply mills and flotation-separation activities.

The Boone Aquifer consists of the Boone Formation where most of the ore occurred. Large amounts of water were withdrawn from the Boone Aquifer to allow for access to the ore deposits during the period when the Picher Mining Field was being mined. Cessation of dewatering activities resulted in the recovery of water levels to their current elevations above the mine-roof elevations. The equilibrium of water levels has been maintained through discharges from mine shafts, vent holes, abandoned wells, and exploration holes whose openings to land surface have elevations less than the water level elevation of the Boone Aquifer. Groundwater elevations in the Boone Aquifer indicate a very subtle north-south gradient. Recharge to the Boone aquifer occurs rapidly following precipitation and continuous recording wells in the mine workings indicate that the mines are hydraulically connected with elevations generally maintained at 795–805 ft above mean sea level.

Groundwater movement between the Boone and Roubidoux aquifers was likely minimal prior to mining activity. However, it is estimated that hundreds of water supply wells were drilled through the Boone Formation and into the Roubidoux to supply mills and towns with good-quality water. Due to the current elevation differences of water levels between the Boone and Roubidoux aquifers, there is a downward flow gradient. Over time, casings and cement seals in the Roubidoux wells will become compromised. This will allow contaminated mine water from the Boone Aquifer to flow into the wells and then downward to contaminate the Roubidoux Aquifer. The EPA and Oklahoma Department of Environmental Quality (ODEQ) have been working since the 1980s to locate and plug these wells. Open mine shafts and subsidence features in the area used for dumping of trash are an additional potential source of further contamination to the Boone Aquifer.

HISTORY OF MINING

The Tri-State Lead-Zinc District in southwestern Missouri and adjoining parts of Kansas and Oklahoma, commonly known as the Tri-State District (Fig. 1), was one of the foremost mining districts in the world. The productive life of the district began with the discovery of lead near Joplin, Missouri, in 1848. A later discovery in Peoria, Oklahoma in 1891 led to the expansion of mining into Ottawa County (Neiberding, 1983). However, the eventual depletion of high-grade ore deposits in the 1930s and the consequent lowering of the grade of mine-run ore caused a gradual and then marked decline in the Tri-State District's output of lead and zinc until the early 1970s when the mining field closed. In most of the intervening years the Tri-State District produced more zinc than any other field in the United States and it generally ranked third or fourth in the United States in lead production (Martin, 1946).

Ore Discovery and Early Mine Development

The first documented discovery of lead in the Tri-State District was reported near Joplin, Missouri in 1848. With the exception of the Galena area of Cherokee County, Kansas, which was discovered and first mined in the 1870s, and limited mining in the Peoria area of Ottawa County, Oklahoma, mining in the Tri-State District prior to the turn of the century was almost exclusively limited to the Missouri portion of the Tri-State District. Because of this limited scope of mining, the Tri-State District was generally referred to as the Southwest District of Missouri or Joplin region until the early 1900s. Southwestern Missouri maintained leadership in domestic metal production through 1917.

The first discovery and earliest mining in Ottawa County was reported in the vicinity of Peoria in T28N, R24E, sec. 12 in 1891 (Weidman, 1932). Although there were some subsequent discoveries and mining operations near Quapaw and Commerce in the early 1900s, the real expansion of mining in the Oklahoma portion of the Tri-State District occurred after a major ore discovery at the current site of Picher around 1914 by the Picher Lead Company. Following this discovery, there was a major expansion of mining in what came to be known as the Picher Mining Field of Oklahoma and Kansas. The Oklahoma portion of this field was fairly well defined by the end of 1917 with hundreds of mining companies developing mines. The year 1918 marked an abrupt decrease in production in southwestern Missouri, as operators abandoned the low-grade mines in that part of the Tri-State District and moved their mills to the richer fields in Ottawa County, Oklahoma.

Mining Leases

Pursuant to a treaty of May 3, 1833, the United States conveyed some 150 sections of land on both sides of what is now the Kansas-Oklahoma state line to the Quapaw Indian tribe, who were originally from Ohio. In 1867, the Quapaws were forced to give up their lands in Kansas. All lands in the Oklahoma portion of the Tri-State District during the period of mining were within the boundary of the original Quapaw Indian Reservation. Under authority of Acts of Congress dated February 8, 1887 and March 2, 1895, the formerly undivided Quapaw reservation, consisting of 56,245 acres, was allotted to 248 Indians, with 400 acres reserved for school and 40 acres for church purposes (Commissioner's Annual Report, 1920). The reservation was subsequently subdivided into 236 200-acre allotments and 231 40-acre allotments (Stroup and Stroud, 1967).

The congressional act of June 7, 1897, allowed individual Quapaw allottees to lease their lands without supervision for agricultural or grazing purposes for three years and for mining and business purposes for ten years. Final approval and administration of all negotiated leases resided with the Department of the Interior (DOI), and in many instances, the lands were leased with the assistance and approval of the DOI. However, numerous Quapaw allottees leased their lands for mining purposes without DOI supervision.

A congressional act of 1921 stipulated royalty rates for Indian allottees and lease agreements that required "All ores or minerals mined or raised on said land shall be cleaned and prepared for market thereon, and no ore or crushed material shall be removed there from to be cleaned, nor shall ore or crushed material from other land be brought or cleaned on said land without the written consent of the superintendent" (U. S. Regulations, 1921). This required a mill to be constructed on each lease. The net result of the lease agreements was that more mine shafts were sunk and mills built than were required to mine and mill the ore under a different lease arrangement. In addition, the lease arrangements required that all mill tailings be left on the lease resulting in mill tailings in all forms being indiscriminately spread across the mining field. By the 1930s, there were approximately 150 chat piles of various sizes in the Picher Mining Field.

During the overall mining period, an average of 25 percent of the lead and zinc produced in the Picher Mining Field came from land owned by individual Indians (Williams, 1930). Few individual mining companies had the capital or other resources to comply with the standard terms and conditions for a 200-acre allotment. As a result, royalty companies, large mining companies, or individual promoters and speculators acquired most initial leases with the Quapaw landowners. These arrangements eventually led to the subdivision of 200-acre allotments into 20- to 40-acre parcels (Stewart, 1984). In the early years, all of these deals were usually in the form of handshake agreements, and as such they were never placed in the public record.

Mining Methods

Mining practiced in the Picher Mining Field is commonly referred to as random room-and-pillar mining where rooms were excavated and pillars were left to support the mine-roof. However, the mining practice in the Picher Mining Field differed significantly from that in other parts of the United States due to the sporadic, nonuniform nature of ore occurrence and the numerous companies that were involved with mining.

A typical, but by no means comprehensive, sequence of the primary mine cycle events involved:

1. Extensive exploration and laboratory assaying to determine the location and grade of ore within a given parcel boundary.

2. Setting up milling facilities and constructing shafts to access the ore body.

3. Primary mining of rooms while advancing away from the shafts to encounter and remove the high-grade ore. The mining approach was left to the discretion of the underground

superintendent (Ground Boss) such that pillar locations and sizes were a matter of personal experience and not based on any preconceived design. Mining was particularly dangerous as evidenced by the following "ladder mining" description:

> ..."*Roof trimming ladders* (Fig. 5) *are made of selected spruce in 20-ft sections. When a 5-section ladder is run out, four guy ropes equally spaced with two men to a rope are used to steady the ladder and tilt it carefully back and forth to cover a little more area". (Eagle-Picher, 1943)*

4. As mines became depleted of ore, a second stage of mining was performed by the mining companies, including pillar shaving (trimming) or complete removal of pillars left during primary mining. After the mining companies were finished removing the higher-grade ore, the mine workings were often subleased to independent miners (gougers) who removed the last remnants of ore from the roof, walls, pillars and floors.

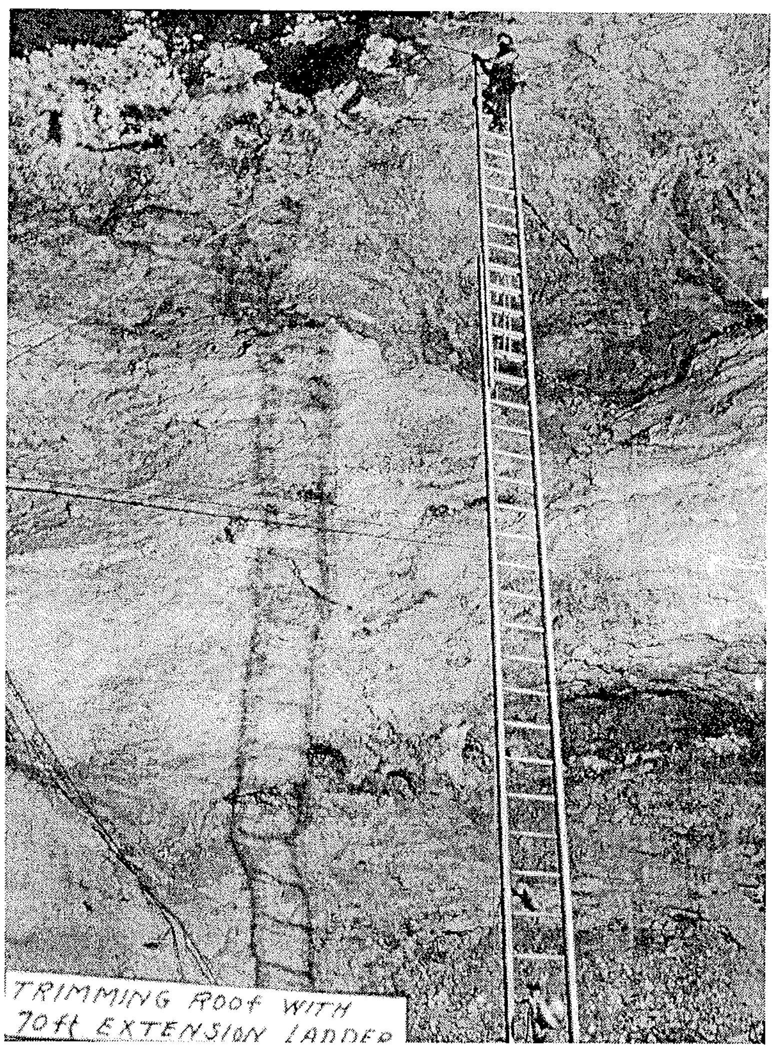

Fig 5. A 70 ft extension ladder used to trim the roof.

Lead and Zinc Production

Prior to 1918, southwest Missouri maintained leadership in domestic metal production. The output of its mines accounted for more than half of the total domestic production of zinc for several years before 1910. Peak production was reached in 1916 when Missouri produced 53 percent of the lead and 65 percent of the zinc mined in the Tri-State District (Brichta, 1959). In 1918, metal production shifted to the Miami–Picher District as mine operators abandoned the low-grade mines in southwest Missouri for the richer fields in Ottawa County. After 1919, 90 percent of the output of the Tri-State District came from the Picher Mining Field (Martin, 1946). By 1926, 227 mills were operating in Ottawa County.

U.S. Bureau of Mines records indicate that a total of 181,048,872 tons of crude ore (Table 1) were extracted from mines within Ottawa County during the mining period 1891–1970, with approximately 85% of the total production coming from the Picher subdistrict (ASARCO Incorporated and others, 1995). A total of 1,686,713 tons of lead concentrate and 8,884,898 tons of zinc concentrate were produced from the crude ore in Ottawa County. The combined lead and zinc concentrates comprised only 6% of the total crude ore mined. The remaining 94% of the crude ore, or 170,185,940 tons, was spread across the landscape in various forms of mill tailings (chat piles, sand piles, flotation fines, and large boulder piles).

Mine Maturation and Closure

The outbreak of World War I increased both the demand and prices for zinc and lead, fueling expansion of the Picher Mining Field. The 1920s were the golden years for the Tri-State District, with peak mine production being attained in 1925–1926. During this period, electric power became available throughout the Tri-State District. Mining and milling practices were further advanced with such innovations as the use of central air-compressing plants and the widespread use of froth-flotation in 1924 by the concentrating mills. Zinc and lead recovered by reworking tailings became an important factor in the total production. The flotation process could recover an additional 25 percent of zinc and 10 percent of lead.

The depression years of 1930 to 1939 saw the demand drop for zinc and lead products, with their values being reduced to less than the cost of production. Due to low ore prices in 1931, all but four mines closed and the mining field was allowed to flood. Mine production declined from a high of 10 million tons in 1925 to less than 2 million tons during 1932. Many mining companies could not afford to continue pumping water from the mines during the depression and ceased operations altogether, never reopening some of the mines. Beginning in 1933, the values for zinc and lead began to increase slowly, and by 1939, the District's production was up to about one half its former averages.

World War II once again increased the demand for zinc and lead during the 1940s. Although the federal government froze most prices and wages in 1942, it instituted a "Premium Price Plan" to encourage mining the lower-grade ores. With this plan, mine production again boomed, reaching more than 9 million tons per year during 1943–1944. During World War II, the level of ore production increased, but never duplicated the glory days of the 1920s. After the end of the war, mine production began a slow decline. Although briefly interrupted during the Korean War, the decline continued until 1957, when most of the larger companies ceased operations. In addition, lead usage was coming under attack from poisoning problems related to paint pigments,

TABLE 1. YEARLY MINE PRODUCTION (TONS) FOR MIAMI-COMMERCE, QUAPAW, AND PICHER SUBDISTRICTS – OTTAWA COUNTY, OKLAHOMA

YEAR	SUBDISTRICT			TOTAL
	MIAMI-COMMERCE	QUAPAW	PICHER	
1907	0	0	0	0
1908	15,000	475,033	0	490,033
1909	91,207	54,546	0	145,753
1910	181,583	40,674	0	222,257
1911	134,560	64,400	0	198,960
1912	202,370	87,829	0	290,199
1913	525,300	55,000	0	580,300
1914	689,987	3,870	0	693,857
1915	613,300	69,200	93,500	776,000
1916	688,100	82,000	616,700	1,386,800
1917	326,500	79,300	3,012,900	3,418,700
1918	85,400	394,700	5,273,800	5,753,900
1919	53,100	730,000	5,206,450	5,989,550
1920	71,000	945,600	5,778,390	6,794,990
1921	8,900	313,300	2,569,400	2,891,600
1922	19,400	1,232,400	4,840,800	6,092,600
1923	99,900	1,653,000	5,971,900	7,724,800
1924	55,200	1,710,400	6,918,500	8,684,100
1925	57,700	1,750,700	8,374,700	10,183,100
1926	126,200	1,726,900	8,028,600	9,881,700
1927	49,400	1,238,300	5,911,000	7,198,700
1928	0	1,367,400	4,160,300	5,527,700
1929	0	1,480,400	4,929,800	6,410,200
1930	4,000	823,700	3,312,900	4,140,600
1931	2,500	160,300	2,043,800	2,206,600
1932	55,000	68,100	1,138,600	1,261,700
1933	30,000	370,100	1,782,100	2,182,200
1934	22,000	496,200	2,048,800	2,567,000
1935	25,000	572,600	2,159,600	2,757,200
1936	15,300	704,400	2,232,900	2,952,600
1937	21,000	502,300	3,264,300	3,787,600
1938	9,200	133,700	2,929,500	3,072,400
1939	11,900	242,100	3,211,900	3,465,900
1940	0	185,929	4,009,471	4,195,400
1941	0	63,442	4,804,579	4,868,021
1942	45,145	441,947	4,525,308	5,012,400
1943	19,013	494,966	4,276,157	4,790,136
1944	6,538	427,455	3,414,678	3,848,671
1945	3,446	270,663	2,957,669	3,231,778
1946	0	208,399	3,434,007	3,642,406
1947	0	90,228	2,672,021	2,762,249
1948	1,310	71,488	2,109,522	2,182,320
1949	0	87,476	2,455,730	2,543,206
1950	5,986	51,378	2,793,516	2,850,880
1951	21,877	204,776	3,315,560	3,542,213
1952	25,371	91,652	3,598,306	3,715,329
1953	6,223	53,350	2,039,127	2,098,700
1954	15,632	61,140	2,677,601	2,754,373
1955	9,243	36,106	2,518,266	2,563,615
1956	8,005	61,180	1,686,422	1,755,607

TABLE 1. YEARLY MINE PRODUCTION (TONS) FOR MIAMI-COMMERCE, QUAPAW, AND PICHER SUBDISTRICTS – OTTAWA COUNTY, OKLAHOMA				
YEAR	**SUBDISTRICT**			**TOTAL**
	MIAMI-COMMERCE	**QUAPAW**	**PICHER**	
1957	891	49,012	850,070	899,973
1958	991	295	382,910	384,196
1959	0	1,400	13,965	15,365
1960	0	0	19,700	19,700
1961	0	0	80,232	80,232
1962	0	0	349,686	349,686
1963	0	4,199	475,603	479,802
1964	0	7,903	478,042	485,945
1965	0	3,613	591,592	595,205
1966	0	1,813	547,500	549,313
1967	0	5,228	437,600	442,828
1968	0	1,312	274,163	275,475
1969	0	0	97,995	97,995
1970	0	0	72,664	72,664
Total	**4,459,678**	**22,604,802**	**153,767,810**	**180,832,290**

Total Mine Production (Tons) for the Five Subdistricts Of Ottawa County, Oklahoma			
SUBDISTRICT	**CRUDE ORE**	**CONCENTRATES**	
		LEAD	**ZINC**
Picher	153,767,810	1,453,711	7,238,764
Quapaw	22,604,802	162,563	1,468,961
Miami-Commerce	4,459,678	62,948	172,093
Melrose[1]	191,262	6,480	2,866
Peoria[1]	25,320	1,011	2,214
Total Production	**181,048,872**	**1,686,713**	**8,884,898**

Note:
[1] **Not included in annual production summary.**

printers' ink, glass and ceramic ware, and anti-knock gasoline; zinc use suffered from substitutions by plastics, aluminum, and epoxy coatings. The principal market left for lead was the lead-acid storage battery; while zinc continued to be used for steel galvanizing, paint pigments, rubber curing, and die-casting.

By 1959, total crude ore production in Ottawa County was only 15,365 tons. As lead and zinc demand dropped, economic hardship fell upon mining communities of the Tri-State District. In April 1959, a congressional delegation visited the mining area, touring the zinc and lead properties surrounding Picher and visiting the Joplin mining area. The hope was that help from Washington might pump new life into the zinc and lead mines. The grim story of unemployment in the mining field was told before the House Interior Subcommittee in Miami. The testimony given at the hearings by mine operators, miners, business representatives, labor, and social agencies in relating the consequences of mine and mill shutdown had an apparent impact on Congress.

The following year, Congress passed the Small Producers Lead and Zinc Mining Stabilization Act (the Act) to provide an economic stimulus for the Tri-State District. Under the program established to implement the Act, groups of miners formed companies and produced crude ore from many formerly abandoned mines under a subsidy from the federal government. Typically, these companies rented the mining equipment already in place and milled their ore production at the central mill or at the sublessor's mill on a toll basis. As a result of this small producers' program, total crude ore production in Ottawa County increased to about 500,000 tons per year during the mid-1960s but decreased rapidly as the program was phased out later in the 1960s. By March 1964, only 281 miners were engaged in the mining industry of Ottawa County (Stroup and Stroud, 1967). By the end of 1967, Eagle-Picher was operating only one mine. Gougers were mining most of the ore. As a result of the selective mining techniques and the lack of discovery of new ore bodies, the Picher Mining Field continued to decline until its final closure in 1970.

POST-MINING LEGACY

A century of mining operations permanently altered the landscape of the Tri-State District, as described in the following subsections. A total of 181,048,872 tons of crude ore were extracted from mines within Ottawa County during the mining period 1891–1970. No industry practices were in place during this period to return processed mill tailings to the subsurface. As a result, mining operations within the District left extensive void spaces in the subsurface. According to Luza (1986), approximately 2,540 acres of the Oklahoma portion of the mining field are underlain by lead and zinc mine workings. Some of the mine workings were as high as 125 feet from floor to ceiling and more than 1,000 feet in length.

Shaft and Non-Shaft Collapses (Mine-Roof Failures)

Surface expression from subsidence of mine workings in the Picher Mining Field has been classified as either shaft or non-shaft-related collapses. Shaft-related collapses could result from a collapse of cribbing used to hold the shaft open during mining and can create a surface depression larger than the original shaft opening. Shaft-related collapses start at the surface and extend downward toward the mine workings (Fig. 6). A non-shaft-related collapse is a surface subsidence feature formed by the collapse of the mine roof in an area where there are usually no mine shafts. Mine-roof failures begin in the mine and cave toward the surface. These non-shaft-related collapses are generally in areas where mining created high room or stope heights in the mine.

The mining era also left a legacy of open mine shafts, shaft-related and non-shaft-related collapse features, more than 40,000 exploratory boreholes, hundreds of abandoned deep-water wells drilled into the Roubidoux Aquifer, large areas prone to subsidence, acid mine water drainage from the mines, poor watershed drainage, and millions of tons of mill tailings containing lead, zinc, and cadmium spread over approximately 7,000 acres of the mining field. At least 1,193 mine shafts existed in the Picher Mining Field in northeastern Oklahoma (Luza and Keheley, 2006). More than 50% of these shafts are concealed and /or filled. There were 511 shafts open and/or in some stage of collapse (Luza and Keheley, 2006). Many shaft collapses begin with the deterioration of the wooden cribbing near the shaft collar. Generally, a 40-60-thick sequence of interbedded shale and sandstone occurs near the surface. This material is highly susceptible to erosion and will cave in toward the shaft opening. Many of the shaft collapses begin small, 20-30 ft in diameter, and can enlarge to over 80 ft in diameter with time. For example, shaft no. 43 on the Harrisburg lease, was a 30-ft circular depression 5 ft deep in November, 1981. In December, 2002, the collapse began to enlarge and by March, 2004, the collapse was a 95 ft wide and 30 ft deep (Fig. 7). Collapses that extend into the underground workings are generally accompanied by spectacular surface collapses 200-400 ft in diameter (Fig. 8). Some open mine shafts had been filled, mostly by private citizens. Some fencing was installed around a few hazardous sites and the Bureau of Indian Affairs initiated a program to fence all Indian owned abandoned mining lands under their control. In 2004-2005, the U.S. Army Corps of Engineers plugged and/or capped 60 open and/or dangerous mine shafts.

At 104 sites, surface collapse appears unrelated to shafts. An area west of Commerce and one west of Cardin have the highest concentrations of non-shaft collapses, 55. The largest non-shaft-related collapse inventoried was a 450- x 320-ft elliptical collapse (2.60 acres) at the Blue Goose No. 1 mine in T29N, R23E, sec 30 (Fig 9). Historically, most collapses took place prior to 1952, but have continued to enlarge. Generally, stripping of the pillars prior to abandonment led to roof instability and subsequent collapse. Some collapses that begin as small subsidence features can enlarge very quickly. A collapse at the Goodeagle and Childress-Heggem Mines, T29N, R22, sec. 25 (1607) increased four times in size over a six-month period. Slumping of the collapse walls continues around and near some of the smaller collapses and new non-shaft collapses have occurred. These new collapses, such as on the Howe, Scott, and Ritz leases, appear related to upper level workings near the surface and/or large stopes in the upper level.

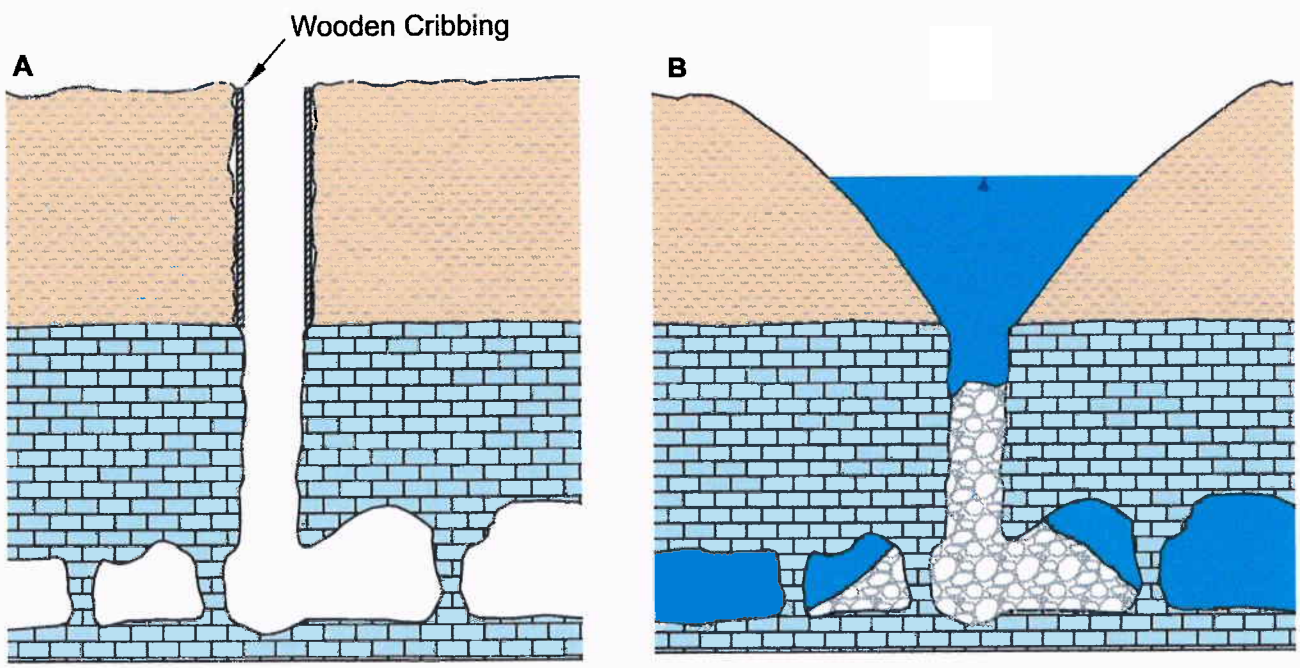

Fig. 6. Schematic cross sections illustrating various stages of surface collapse associated with shaft failure. A, typical open shaft and underground mine workings before the mine workings filled with water. B, advanced stage of shaft failure with mine workings filled with water.

Fig. 7. Large shaft collapse on the Harrisburg lease (T29N, R23E, sec. 19, no. 43) that began to enlarge in 2002.

Fig. 8. Aerial view of a 4.04-acre collapse associated with two shafts at Domado Mine (T29N, R23E, sec. 29, nos. 1-2). Photograph courtesy of Rebecca Jim, L.E.A.D. Agency.

Fig. 9. Aerial view of the largest non-shaft collapse (2.60 acres), Blue Goose No. 1 Mine, T29N, R23E, sec. 30 (1511).

Very little destruction of buildings and roads has resulted from surface collapse. However, on July 21, 1967, 18 persons occupied houses that were affected by a 1.5-acre collapse on the Netta White lease north of Picher High School. Five minor injuries resulted from the collapse. Two houses were in the center of the collapse, and one house on the lip was tilted 25^0 from the horizontal. An attached garage of a fourth house on the rim of the collapse was broken away from the house and severely crumpled. The surface near the center of the collapse was dropped about 25 ft (Fig. 10). At least one fatality associated with an automobile accident can be attributed to a non-shaft collapse. On 31 May 1978, a cave-in was observed about 8 a.m. on the south side of east A Street, T29N, R23E, sec. 23 (no. 1553). By noon the cave-in had reached the center of the road. The cave-in area was about 90 ft long, 40 ft wide, and 50 ft deep.

Ground-Water Inundation

During active mine development and production, groundwater entering the mine workings was pumped to the surface and discharged. As the size of mine workings increased, the overall volume of groundwater entering the mines increased. During peak mining periods, as much as 26,000 gallons per minute of groundwater were pumped in the Picher Mining Field to keep the mines dry.

This water was primarily handled at centrally located pumping stations that were collectively operated by the mining companies. Mining companies began to reduce pumping in 1955, and by

1957 pumping was only occurring on a part-time basis. As a result of these actions, water in the southern part of the field had risen by 22 feet by 1968. By 1969, pumping had ceased entirely and all remaining pumps had been pulled from the District. The main body of water in the

Fig. 10. The 1967 collapse in Picher, Oklahoma, north of the Picher High School that caused damage to personal property.

southern portion of the Picher Mining Field rose 32 feet that year to an elevation of 558 ft. In 1970, water rose another 18 feet in Section 30.

Most of the mines were inaccessible by that time except for those in the northwestern part and some of the upper levels. After the abandonment of all pumping operations, complete flooding of the mine workings (approximately 76,000 acre-feet) occurred by 1979.

REGULATORY OVERSIGHT OF MINING OPERATIONS

Federal and state regulators provided little oversight of mining operations on non-Indian lands during the mining years. All mining operations were under the Oklahoma State Mining Code. Prior to 1920, the state of Oklahoma developed an elected position of State Mine Inspector who had authority only on non-Indian lands in Ottawa County. The local mine inspector was elected by popular vote, rather than a selection based on qualifications. Prior to 1965, the U.S. Bureau of Mines (USBM) primarily provided professional mining services to the U.S. Bureau of Indian Affairs (BIA) rather than enforcement of safety regulations. Federal inspection of mines on Indian owned lands by the U.S. Bureau of Mines Health and Safety Division became effective in 1965.

Prior to the act of 1921, the DOI did not exercise supervision through the Quapaw Agency of lead and zinc production from mines on Indian lands on the Quapaw Indian Reservation. The reconstruction of production records prior to 1921 later proved difficult; no data was available at the Quapaw Agency relative to the production of ore from the old Peoria and Lincolnville camps or the production from the Miami and Picher camps made prior to 1917 (Williams, 1930). The Miami field office of the U.S. Geological Survey (USGS) was established under a cooperative agreement with the Office of Indian Affairs in 1923. Under the agreement, the USGS provided the first oversight of mining operations on Indian-owned lands. Detailed records of production, sales, and royalty-leased and subleased mines were maintained from that date forward.

The major safety concerns in the mines besides falling rocks and unsafe handling of dynamite were excessive mining of the mine roof, and trimming and removing support pillars. Throughout the mining period, it was a common practice of the mining companies to remove or trim any pillars containing high levels of lead and zinc before the mines were abandoned (Eagle-Picher, 1943; Weidman and others, 1932). The decision to remove or trim supporting pillars was made primarily by the mine operators without approval of the state or federal mine inspectors. Around 1950, the few remaining large mine and/or mill operators who still operated mills began to sublease less productive mines to small independent mine operators, who would mine the last remaining ore and sell it to the mills. The small operators would often lease the mining equipment left underground by the larger mining companies.

A formal process was established to control pillar removal on Indian-owned lands by the USGS and the USBM (Westfield and Blessing, 1967). A three-member committee comprised of representatives from the USGS, USBM and the State of Oklahoma Mining Inspector was established. Mine operators were required to request advance permission from the committee to trim or remove pillars. Each pillar request was evaluated by the committee, and a determination was made based on the safety considerations of removing or trimming the pillar. The committee was in place until 1970, when the mining operations ceased.

TAR CREEK FIELD TRIP STOPS

STOP 1. OVERVIEW FROM THE MAHUTSKA CHAT PILE, PICHER, OKLAHOMA

Introduction

Picher, Oklahoma is located in the heart of the once busy Picher Mining Field in Ottawa County in northeastern Oklahoma. The "mother lode" or richest deposits of lead and zinc ore were found beneath the city of Picher and the surrounding area. Picher did not exist before the start of mining in the area. Picher came into existence because of the need for a place of commerce to support the new mining industry. There was a need to centralize a location where miners could live, mining company offices could be located, mining equipment could be shipped in and ore concentrates shipped out.

Just before the First World War, it became evident that the mining around the Joplin area was headed for a decline and the Picher Lead Company decided to bolster its supply of concentrates by seeking mines in Oklahoma. O. S. Picher and A. E. Bendelari of Joplin leased approximately 3,000 acres in northeast Oklahoma. A drilling campaign was initiated in 1913 between Commerce and the Oklahoma-Kansas state line, west of the present town of Picher, in an attempt to develop an extension of the Commerce field, where the ore bodies had a north-south trend, slightly west of Commerce. Although ore was found in some of the holes, results of the drilling were not encouraging, and it was decided to abandon the effort.

One of the drill rigs, while returning to Joplin in 1914, became mired in a slough on the prairie just east of Tar Creek in what is now the northwestern part of Picher. The site is located just north of "A" Street and about 200 yards west of Highway 69 on the Ethel Crawfish allotment, which was under lease by the Picher Company. Records vary as to whether the drill rig operator asked permission or Picher and Bendelari directed the operator to drill a hole on the spot in order to recoup some of the loss from being stuck in the mud (Miami Daily News Record March 27, 1940; Anonymous, 1943). Whatever the case, a rich strike was announced on August 2, 1914. Most of the historical documents state that the decision to abandon drilling was made in 1914. But, a book (Prairie Jackpot, 1973) by Howard Blosser, whose father, Dick Blosser, did the actual drilling and who himself worked on the drill rig, states that the strike was actually made in 1913 and that Picher and Bendelari kept it a secret until they could finalize lease agreements in the area.

Drilling was centered around this discovery and led to the quick development of the Crawfish, Netta, Whitebird, and Bingham mines. By the summer of 1916, four large mills were operating on these properties (Anonymous, 1943). Within three years more than 800 drill rigs were prospecting the area to expand the ore findings.

Picher, Oklahoma

Picher, named after O. S. Picher, was a tent city at first. Thirty-day leases on 25 foot lots were grabbed and sold and resold, many of them doubling and tripling in price. The mud was so deep and gummy that a pair of gum boots was standard equipment for women and children.

Work in the early days was not hard to find for those looking for a job. There was more than enough work since most of the young men were away in the war, and wages were high. The problem was to get men to do the work. Soon there were Doctors, lawyers, businessmen and families arriving in the area. Grocery, clothing and hardware stores, and hotels were quickly built as well as a hospital and Post Office.

A Daily Oklahoman newspaper correspondent wrote on August 12, 1917. "This is the story of gold. Fifty square miles of gold. That is what the Oklahoma zinc and lead mining district is today. It will be a good deal bigger a year from today—how much bigger, nobody can say. The golden area is growing constantly, swiftly. Drill derricks are sprouting up multitudinously. You see them everywhere. They punctuate the prairie now. They fairly leap at you from the midst of corn fields. You see the derrick's ugly shape breaking the verdure of timber land. There are hundreds of these drills chugging the incessant chorus of their search for ore. And they are finding ore with astonishing electrifying regularity. The town of Picher has sprung up from the prairie. Its forced growth has necessarily been of the shack character. There it sprawls on the open plain, a gangling, awkward disheveled characreature, hot as an inferno under its noon sun, and treeless as a desert. Up and down its main street the traffic of the district swings ceaselessly; taxis sweating in from Miami and Joplin or returning; motor trucks creaking under their loads of machinery; ore wagons lumbering slowly past; and clouds of dust swirling forever............. Such is the town of Picher, and such are all the other mining towns in the field."

Concerning government and law enforcement problems in a mining camp, the same writer observed that the Eagle-Picher Company, having leased the mineralized lands from the Quapaw Indians, maintained a sort of ''feudal organization'' over the community. Gibson wrote in 1967, "The company employs a deputy sheriff who has authority to enforce regulations where needed. The social organization of these mining communities is rather feudal in character. . . . . Mr. A. E. Bendelari as the company's representative is a sort of overlord, a court from whose judgment there is no appeal. He administers the law of the land. Community differences which inevitably arise are brought to him for adjudication when the litigants are unable to effect a settlement themselves. Company control of the land vested its representatives with the power to make his judgments binding. Anyone who refuses to accept the court's finding can be dispossessed of his home. Rarely is this extreme penalty imposed".

Picher was incorporated as a village on March 4, 1918. A five member Board of Trustees was elected to manage the town. The Picher Company donated $400 to the city "to be used in keeping up a high state of morals in the city" and donated land for construction of a jail. Ordinances were soon adopted to levy dog taxes, license pool halls and to prohibit street and public grounds excavation, lewd conduct, cheats and frauds, petty larceny, the carrying of weapons, obscenity and profane language, jumping upon or hopping moving vehicles, swine in certain sections, firecrackers, and prohibited prostitution couched in terms of courtesan, promenading, and bawdy house.

By 1920, the Eagle-Picher Lead Company's deep well water tower was lettered with the words, "Picher, in 1920 a city of 20,000" (Miami Daily News Record, March 27, 1940). On November 14, 1921, Picher was officially incorporated as a 'city of the first class" under the laws of the state of Oklahoma and the first Mayor elected. By that time Picher's population had grown to 10,000. Picher's population later reached 22,000 (Figs. 11 and 12).

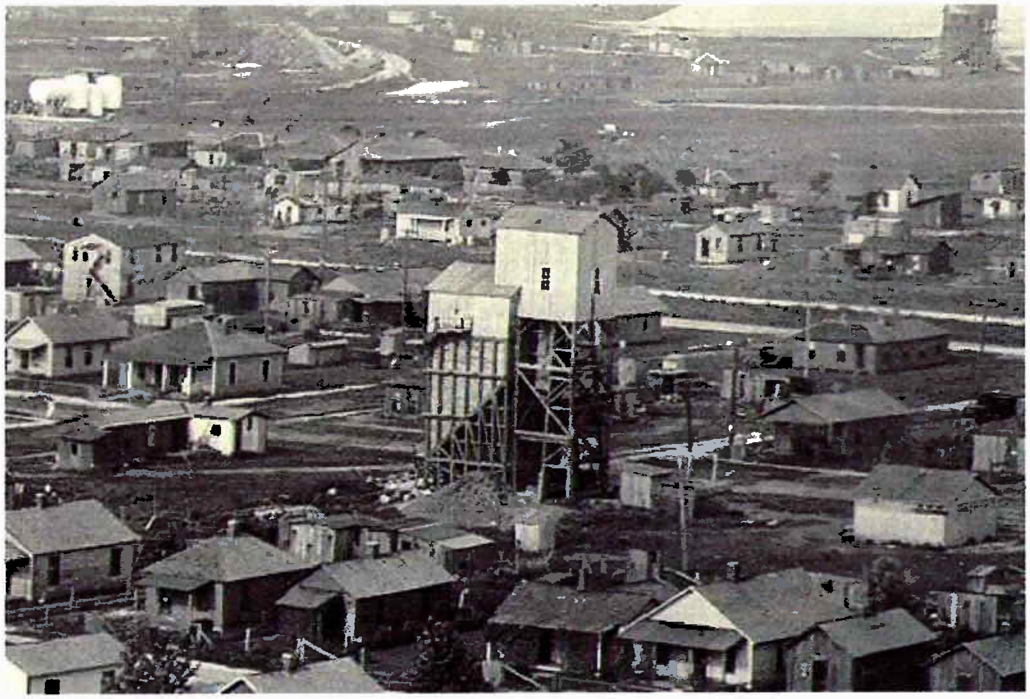

Fig. 11. Early years in Picher, Oklahoma.

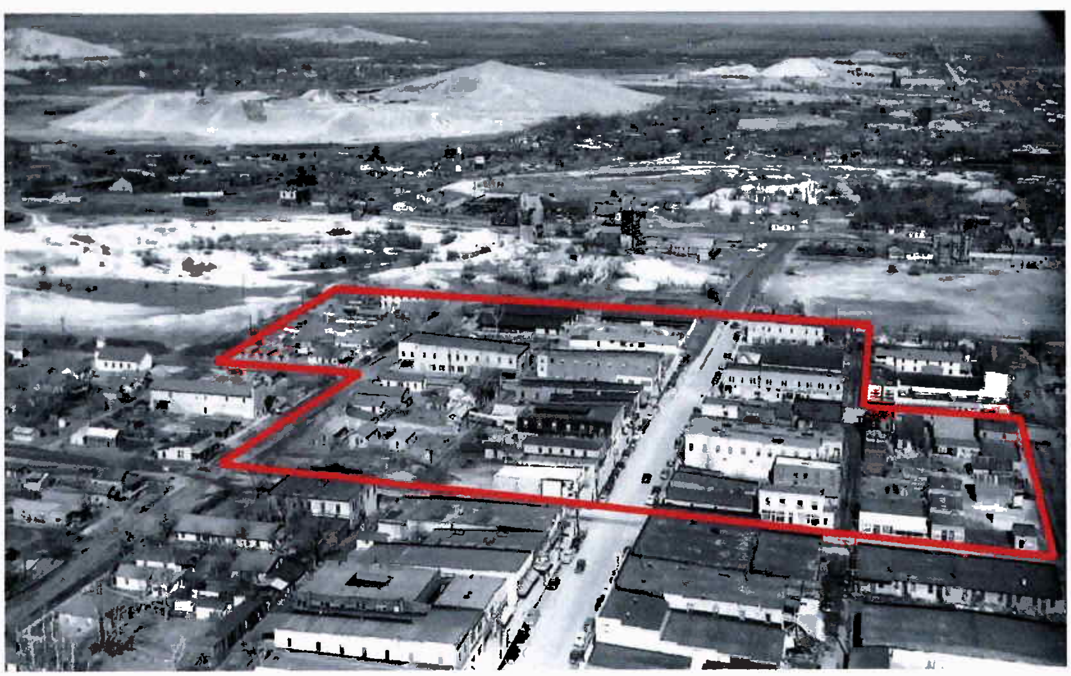

Fig. 12. Downtown business district in Picher, Oklahoma. Area outlined in red was impacted by Eagle-Picher's February 8, 1950 eviction notice (see pages 30-31).

The city of Picher was not destined to achieve the benefit of orderly physical and economic growth characteristic of most urban communities. The discovery and exploitation of lead and zinc in the area resulted in accelerated, but haphazard development. Although Picher was platted, much of the town site was covered by mill tailings and mill ponds by 1920 (Fig. 13). The mining companies had first priority over land use leaving the city to be built on the remaining land.

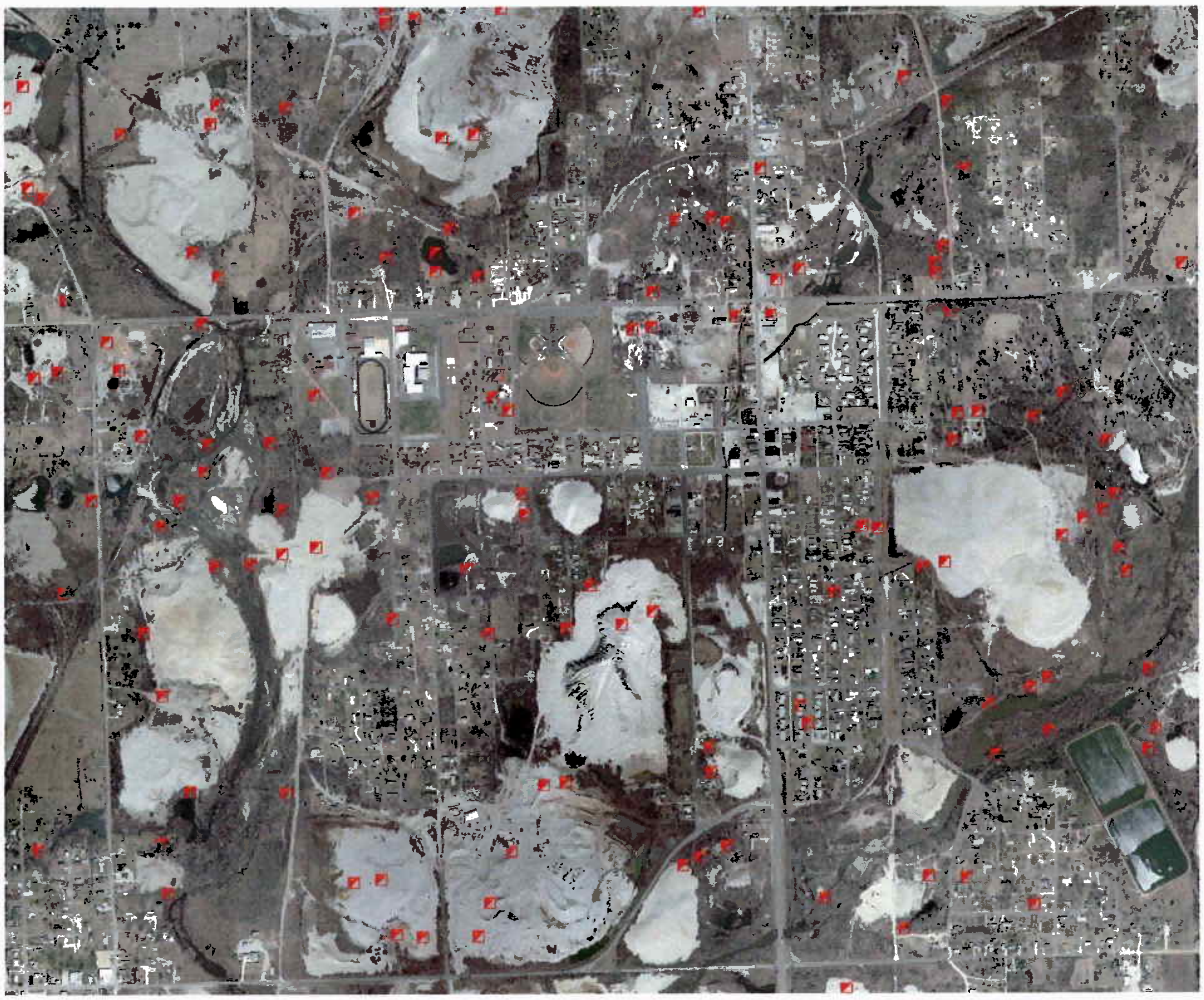

Fig. 13. Chat piles, former chat piles, former tailings ponds, and mine shafts (shown in red) in Picher, Oklahoma.

The peak of the mining in the Picher field was in the 1920s. During the great Depression of the 1930s, Picher began a slow decline as a result of economic hardship and the absence of new ore bodies available to mine. Mining activity increased slightly during World War II and the Korean War, but steadily declined in the 1950s. The economy of Picher has historically been tied to mining. The city got its start as a mining community and owes its existence, as well as its problems, to the mining industry. As long as the mines were operating at a pace approaching full production, the town prospered, but with the shutdowns starting in 1957 the residents found themselves without incomes and the city found itself without an economic base. Mining continued to decline until 1970 when the mines and mills ceased operations for the last time.

Comprehensive Plan for Picher

In 1964 in order to address the historical stigma of being a mining town, the city of Picher requested the Oklahoma State Department of Commerce and Industry to assist them in developing a comprehensive plan for the city (Picher Comprehensive Plan, 1964). The Plan was prepared to establish guidelines to upgrade the community environment, stabilize property values, provide community facilities and services, and encourage an atmosphere favorable to economic and social well being. The purpose of the comprehensive planning program was to obtain the best possible development and redevelopment of the city of Picher. The goal of the program was not only to improve the physical appearance of the community, but to solve social and economic problems as well.

The Plan identified numerous issues affecting Picher's ability to recover from the "Boom Town" stigma. Picher experienced a 56 percent population loss between the 1940 census and the 1960 census of population as the mining industry declined. There was also a sizeable loss of the productive population between the ages of 20 and 44 due to the absence of employment opportunities in Picher. The general deterioration of the town occurred due to the loss of basic employment, which restricted the effective tax base. Many businesses were boarded up and others simply deteriorated. The surrounding communities of Quapaw, Commerce and Miami suffered general deterioration as well, but not as severe as Picher and Cardin.

The Plan pointed out that almost 40 percent of Picher was covered by chat piles and sumps and remains the same today. The large amount of restricted Indian land in Picher was also viewed as a potential obstacle to planned development. These conditions have not changed in the past 40 years.

The Plan concluded that the extensive mine workings under the city, the amount of surface area covered by mill tailings, 90 percent substandard housing, the deteriorated business district, inadequate room for industrial growth and the size of the city being too large for the number of residents, worked against the possibility of future commercial and industrial growth. In the final sense, Picher was considered to be located in an area unfavorable for commercial and industrial growth and too dilapidated to rehabilitate. No funds were ever provided to Picher to implement the few recommendations that might have improved the city.

According to the 2000 population census, Picher had 1,640 residents. In 2005 a voluntary buyout of residents with children under six years of age initiated by Oklahoma Governor Brad Henry resulted in 52 families accepting the buyout. During the same time period additional residents moved from Picher due to their dissatisfaction with the EPA yard remediation program and the lack of concern for their circumstances by elected officials. Most of the businesses remaining in Picher in 2000 closed their doors by 2005. The population in Picher in 2006 is around 1,000 residents.

Chat Piles

The terms of the early mining leases required exploration work upon the leased land to begin almost immediately and to continue in good faith, without interruption, until ore in paying quantities was discovered. Many leases even specified the number of drill rigs that had to be on the property. After ore was discovered, the leases required that the ore body be developed and put into production at once and the leases frequently specified what type of developments and facilities were required on each 20 or 40-acre mining unit. For example, the standard lease contract after a Congressional Act of 1921, stipulated that "All ores or minerals mined or raised on said land shall be cleaned and prepared for market thereon, and no ore or crushed material shall be removed therefrom to be cleaned, nor shall ore or crushed material from other land be brought or cleaned on said land without the written consent of the superintendent". This required that a mill be constructed on each lease regardless of the size of the lease. The regulation required more concentrating mills built than was actually necessary to process the mined ore. The net result was an excessive number of mill tailings (chat) piles created by the mills. As a result, mill tailings were spread over a large surface area to meet the leasing regulations.

As a result, large areas of land previously available for agricultural use were used to store mill tailings. Stroup and Stroud (1967) reported that approximately 5,000 surface acres were overlain by mine and mill tailings. Some tailing piles attained heights of nearly 200 feet. The former Eagle-Picher Central mill tailing pile north of Commerce was among the tallest and near the end of the mining period contained approximately 12 million tons of tailings. It was removed following the closure of the mining field except for the base material.

Although a limited amount of crude ore being milled in the early mining days ran as high as 9% combined zinc and lead content, the average contained about 4 to 4.5% making the mining field the lowest grade in the world. Near the end of the mining period the average content was around 2% combined zinc and lead content.

The crude ore from the Picher field was actually richer (higher grade) than that from the Missouri portion of the District and contained a larger percentage of finely disseminated zinc mineralization. The purity of the zinc and lead was higher in the Picher field and actually ranked among the highest in the world. Because of the low zinc and lead content of the crude ore, the mining and milling concept/design was based totally on processing a high volume of material per unit time in order to make an adequate profit.

Because of the characteristics of the crude ore from the Tri-State District, the basic milling practice used to extract the bulk of the zinc and lead was gravity concentration. For at least two reasons gravity concentration was the principal tool of milling in the Picher field; namely, the hardness of the flint and the low value of the principal economic mineral, zinc. Flint is one of the hardest rocks to grind fine resulting in higher milling costs. Gravity concentration, as developed in the District, utilized jigging and tabling to remove the waste material from the zinc and lead mineralization.

Because of the low grade ore in the Picher Mining Field approximately 96 percent of the crude ore milled ended up as tailings. Given the total crude ore production of 181,048,872 tons from the Picher field, there would have been approximately 139,000,000 tons of tailings (chat) not including 21,000,000 tons of sand tailings and 14,000,000 tons of flotation tailings produced (ASARCO Incorporated and others, 1995).

Approximately 150 chat piles were created from the mining and milling operations during the mining period. Today most of the chat piles have been removed and only the chat bases are still visible. Only about a dozen of the larger chat piles remain today and two of those are currently being removed. The larger aggregate in the chat piles is being used in asphalt mixtures for highways. The finer chat particles in the <40 mesh size are being left on-site following the washing and screening process.

Elevated Blood Lead Levels in Children

Numerous studies have shown that the finer mill tailings contain high levels of lead, zinc, and cadmium. Lead in young children is known to cause permanent neurological damage. Blood lead data collected by the Indian Health Service (IHS) between February 1992 and May 1993 indicated that 35% of the children tested had blood lead levels greater than or equal to 10 µg/dL (Ackerman, 1994). The actual source(s) of the lead exposure for the children with elevated blood lead levels was unidentified, but several possible sources were noted, including living in proximity to chat piles. It was estimated that a "small majority" of the children lived within 5 miles of chat piles. In addition, investigations of mining waste at the Cherokee County, Kansas and Jasper County, Missouri, Superfund sites indicated that the levels of lead, cadmium, and zinc found in chat and flotation pond sediments may pose a significant risk to human health and the environment (ATSDR, 1994a). The study found that blood lead levels were significantly higher in the population exposed to mining waste compared to the control group.

From August 1994 to July 1995, the EPA conducted sampling of soils in high access areas, (e.g., day care centers, school yards, and playgrounds) and residential properties in the Tar Creek Superfund Site. On August 15, 1995 the EPA issued an Action Memorandum which called for the excavation and on-site disposal of lead-contaminated soil in high access areas. On August 25, 1995, the EPA issued a notice to the former mining companies or to their corporate successors and the U.S. Department of the Interior (DOI) as potentially responsible parties (PRP) under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In that notice, the EPA gave the mining companies and DOI the opportunity to conduct or finance the removal activities. The companies and DOI did not choose to undertake the removal; consequently, the EPA proceeded with the removal action for the high access areas on its own.

During the period of April to July 1995 the EPA, Region 6, Technical Assistance Team (TAT) contractor, Ecology and Environment, Inc. (E&E) collected data to delineate the nature and extent of the residential contamination. The TAT compiled data was used to prepare the Baseline Human Health Risk Assessment (BHHRA).

The EPA also issued a Special Notice to the mining companies and to DOI on November 17, 1995. In the Special Notice, EPA gave the companies and DOI the opportunity to undertake the Remedial Investigation and Feasibility Study (RI/FS) and remedial design (RD) for the remedial response action to address contamination in the residential areas of the site. The companies and the DOI did not agree to undertake the RI/FS/RD. As an alternative the companies and the DOI offered to perform a Community Health Action and Monitoring Program (CHAMP). The CHAMP generally called for monitoring the health of the children in the contaminated residential areas, for thorough cleaning of homes in the contaminated area, and for education of the residents regarding the avoidance of contamination. The EPA encouraged the companies and the DOI to undertake the CHAMP, which they did. Unfortunately, housecleaning and education do not provide the sort of permanent remedy that the superfund law requires. Consequently, EPA went forward with the RI/FS/RD on its own.

In order to address the "imminent and substantial endangerment to human health posed by lead-contaminated soil in the residential areas on the site," the EPA issued a March 21, 1996 Action Memorandum calling for a removal action to address the contamination in residential areas. At the time the Action Memorandum was issued, EPA sent a letter to the mining companies and the DOI notifying them that EPA was proceeding with the removal of soil in residential yards. In the letter, the EPA informed the companies and the DOI that EPA would not delay the removal action in order to negotiate; however, the EPA gave the companies and the DOI the opportunity to conduct or finance the removal activities in progress. The companies and the DOI did not offer to take over the removal actions.

Remedial actions of the residential areas originally began in June 1996 as an emergency removal and continued in January 1998 as a remedial action. During this same period, the EPA contractor, E&E was preparing the BHHRA. The final report of the BHHRA was issued in August of 1996. Concurrently, the U. S. Army Corps of Engineers (COE), Tulsa District, under an Interagency Agreement with the EPA, Region 6, was preparing the Residential Remedial Investigation portion of the RI/FS. The RI was issued in January 1997.

The EPA the yard remediation project was ongoing in April, 2006. Over 2,500 residential/school yards were remediated at a cost of over $150 million. Blood lead levels decreased during the years of the yard remediation project. Concurrent with yard remediation, the Ottawa County Health Department conducted an education program with affected families to teach proper hand-to-mouth behavior in children and home cleanliness to address the problems of lead dust in yards and households. A program of remediating homes containing lead-based paint under a Housing and Urban Development grant was also utilized to address the problem. Data was not collected to determine the actual contribution of the yard remediation project to the reduction in blood lead levels in young children.

Chronology of the Netta Mine(S) in Picher, Oklahoma

Mining and Milling History

The last remaining hopper in the entire Picher Field is located on the East Netta mine in downtown Picher, Oklahoma (Fig. 14). Netzeband (1929) provides a description of some of the history and operation of the East Netta mine. The first prospect drilling by the Eagle-Picher Company at the Netta mine occurred in late 1914 and shaft sinking was started early in 1915. Sufficient ore was developed to start construction of the mill in April 1916 with production following in August 1916. The property was originally a 40-acre tract (East Netta), but additional properties were consolidated with the original one until the mine covered 200 acres. The 200 acres included the following leases; East Netta 40, West Netta 40 (formally the Perin mine) and the Dorothy Bill No.2 80 acres in T29N R23E sec. 20, and the adjoining Netta White 40 acres in T29N R23E sec. 17 (Fig. 15).

The mill (south of the hopper) had a capacity of 1,400 tons per 24 hours making it one of the largest mills in the district. It was one of the first in the district to use the flotation process to concentrate ore by adding a flotation plant in 1917.

At least three main levels occurred on this lease. Mining depths varied from 190- to 260-feet below the surface. Most of the ore was mined from the M and G-H beds. Ore also was mined

Fig. 14. Last remaining hopper in the Picher Field now located on the East Netta Mine (shaft no. 26 on the figure below).

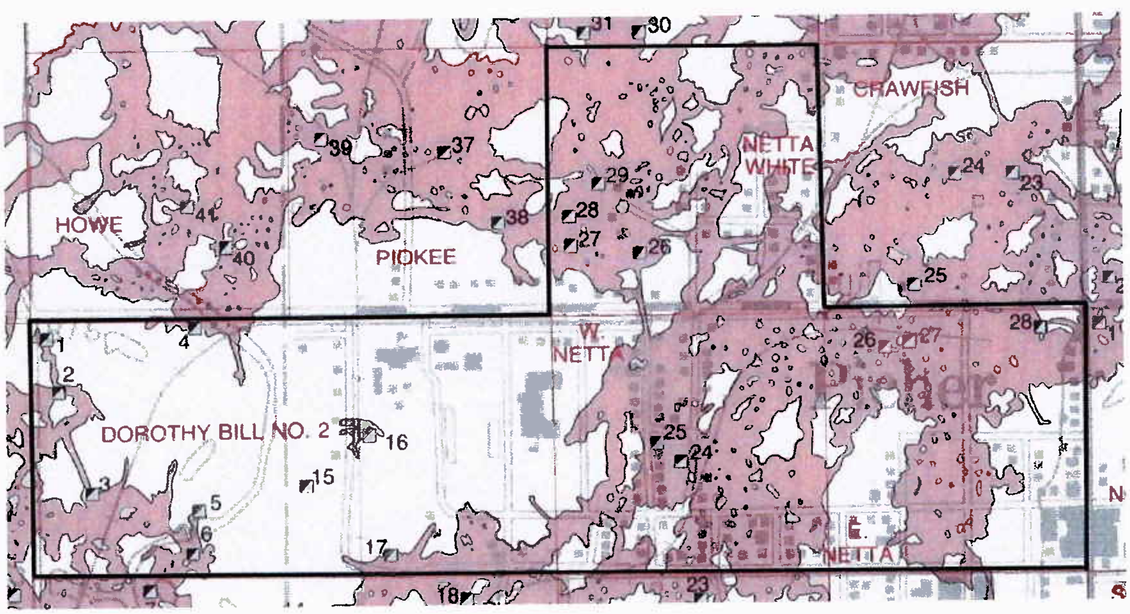

Fig. 15. The Netta mines: Dorothy Bill No. 2, Netta White, West Netta, and East Netta.

from K and E and Chester beds, but in lesser amounts. The deepest level was at about 260-feet, the middle was at about 220-feet, and the upper was at 190-feet below the surface. Lower level stopes were 10-to 96-feet high and from 50-to 750-feet wide. Ore was mainly from the M-bed on this level. In the larger stopes, 60-to 96-feet high, a number of beds were simultaneously mined. Middle level stopes were 150- to 200-feet wide and 8-to 12-feet high. The principal ore bed mined on this level was G-H. The upper level workings were limited to the south end the lease. Stopes on this level were up to 200-feet wide and 9- to 10-feet high. Ore from E and Chester beds were mined on this level. Two large rock falls, which cover several acres, are located in the northeast corner of the lease. About 65-feet of alluvium and shale overlie the Hindsville Limestone on this lease. The Hindsville Limestone is 60- to 65-feet thick and extends across the entire lease.

The usual practice in the district was to sink a shaft to an isolated ore body and tram the ore on the surface rather than to connect underground and hoist at a central shaft. For this reason, the mines usually had two or more "field" shafts for hoisting ore besides the mill shaft. The main or mill shaft was originally sunk at the mill site on the original East Netta tract to the 260-foot level, which was the main haulage level for the mine. All ore was hoisted at the mill shaft. The shaft was five by seven feet in cross section, the standard size for shafts in the district. It was close-cribbed with two by six inch pine lumber from the collar of the shaft to a point below the shale. Originally it was equipped with the usual Joplin-type hoist using standard cans holding about 1,400 pounds of ore to bring the ore to the surface. The shaft was later equipped for a skip hoist in 1920 using two and a half ton self-dumping skips and hoisting in balance. Before the various properties were consolidated, several shafts were sunk on each tract, ultimately there were14 field shafts on the 200 acres.

According Netzeband ((1929), the mine was supported almost entirely by pillars of ore from 20- to 60-feet in diameter, averaging about 30-feet. The size depended upon the character of the ground and the height of the roof. The pillars were spaced 40- to 100-feet, center to center, with an average spacing of 80-feet. Wherever the ground permitted, the roof was arched. There were parts of the mine where thick shale or loose boulder ground necessitated timbering, but generally these parts were not ore-bearing and only "pull" drifts were driven through them.

The initial the extraction ratios on the East Netta was about 85%, however, many of the pillars were recovered before the mine was abandoned (Netzeband, 1927). As early as the late 1920s, some of the pillars had been removed and others trimmed down as small as considered safe. As of 1929, none of the trimmed pillars appeared to show visible signs of taking on weight. After the Eagle-Picher central mill was built in 1932, the skip-type hoist was removed from the mill shaft and a metal derrick with a hopper was built in its place. The ore from the mine was collected in the hopper and transported to the central mill by rail for milling. The Netta mill was shut down shortly thereafter and was only operated occasionally to remill the chat tailings adjacent to the mill.

Reunion Park

Mine maps of the East Netta mine show that by 1940 many of the pillars had been trimmed or completely removed to obtain the rich ore before the mine was abandoned. A good example of this practice is the area beneath the Picher Reunion Park. Mine maps in the 1940s and 1950s show a large mined void beneath the park as a result of mining on multiple levels and the tops of pillars on the west and southwest perimeter of the mined area were missing. The missing tops probably are related to the removal of an additional 50 ft of ore from the roof at this location in the early 1940s. The adequacy of the remaining pillars to support the large void has been questioned by former miners and residents for many years. A large pillar near the center of the void beneath the intersection of Main and Second Streets is 94-feet high and less than 50-feet in diameter. Adjacent to the pillar, the mine void reaches a maximum height of 106-feet. According to local newspapers, in 1940 Eagle-Picher became concerned about the structural stability of the main pillar supporting the void beneath the intersection of Main and Second Street. A decision was made to pour a concrete support sleeve around the existing pillar. Concrete and reinforcing materials were used to encapsulate an existing pillar to a height of approximately 50-feet from the floor of the mine. Some of the concrete was poured down drill hole no. 59 near the intersection of Main and Second Street. Maps of the East Netta mine from 1920 through 1967 showed the following:

- At least 43% of the pillars from First Street on the south, to "A" Street on the north, have been removed and 23% have been significantly trimmed.
- At least three rock (roof) falls between 100 and 300 ft in diameter have occurred in the area where the pillars were removed or trimmed. The largest occurred before 1946 and the smaller ones between 1957 and 1967. In the northern part of the East Netta mine where the rock falls occurred, 8.74 acres are identified as "Restricted" on the latest mine map. The area is bounded by 'A' Street on the north, First Street on the South, and Connell Ave. on the East.
- Based on a review of mine maps for the years 1946 and 1954, mining continued in the East Netta portion of the mine. Mining of the high upper (third level) in the southwest part of the East Netta was completed and a new upper level was mined on the east side.
- Mine maps prepared by Stewart Engineering about 1954-57 show the tops of at least eight of the main support pillars on the west and southwest perimeter of the large void under Reunion Park missing. The mine maps also identify two small pillars north of the reinforced pillar as taking on weight, sloughing and showing signs of fractures.

The threat of possible future collapse of additional areas was made a reality in February 1950 when the Eagle-Picher Mining and Smelting Company issued notices to tenants to vacate five city blocks (8.45 acres) in the heart of the business district of Picher within 30 days (Fig. 16). Eagle Picher officials formally notified Picher city officials and tenants in the area that, "You should vacate the area immediately for your own safety" (Miami News Record, Feb. 7, 1950). The President of Eagle Picher stated, "While no one can say with any degree of certainty as to when any given mine area will cave, we do feel that there is now sufficient evidence of possible hazard to those using the surface that we are duty bound to give warning of the hazard at this time; hence the notices issued today" (Joplin Globe, Feb. 8, 1950). Two pillars beneath the heart of the business district were described as showing signs of taking weight and showing signs of stress. Eagle-Picher officials took Picher city officials on a tour of the underground workings to point out the reasons for the need to vacate the area.

Shutting down the heart of the business district was a serious blow to the city of Picher. Additional space in other parts of the city was not available to absorb the businesses displaced. The vacant 8.74-acre area north of the condemned area was not available since it was restricted for use by Eagle-Picher. Although a few businesses relocated to other areas of Picher, many simply closed their doors. Subsequently, all of the buildings and residences were demolished and a high chain link fence was built around the area to prevent access.

Fig. 16. Approximate area that Eagle-Picher ordered vacated in February, 1950

Between 1954 and 1957 the city of Picher hired the William M. Stewart Engineering Company of Joplin, Missouri to conduct an independent assessment of the stability of the condemned area in Picher. As part of the assessment, Stewart Engineering developed a series of cross sectional maps of the East Netta mine including the area where the concrete reinforced pillar is located. The maps clearly show that the concrete reinforcement of the pillar in the center of the large void extends from the floor of the mine to approximately half way up the pillar. The maps also show that the recommendation following the conclusion of the engineering assessment was that the site was too unstable to reopen for public use.

In June 1967, the city of Picher was presented a quitclaim deed from Eagle Picher for the fenced area on the East Netta mine site and a small adjacent area comprising 10.92 acres.

West Netta

The West Netta mine is on a 40-acre lease in NW1/4 NE1/4 sec. 20, T. 29 N., R. 20 E. Mine-workings depths ranged from 165- to 270-feet below the surface. Ore was mined from three main levels. The lowest level was at 265-270 below the surface. Stope widths were up to 240-feet and working heights ranged from 12- to 22-feet. Ore was mined from the M bed at this level. Middle level workings occurred at about 236-feet below the surface. Middle level stopes were up to 200-feet wide and 8- to 33-feet high. Ore was mined from K bed at this at this level. The upper level workings are found on the east and west sides of the lease. Upper level workings occurred at 188- to 205-feet below the surface. Stopes on the upper level were up to 250-feet wide and from 7-to 20-feet high. The principal bed mined on this level was G-H. About 100-feet of alluvium and shale overlie the Hindsville Limestone. The Hindsville Limestone is up to 60-feet thick.

On Saturday morning July 22, 1967 an area 250- by 300-feet collapsed on the northwest side of Picher in the Netta White mine within eight hours of pillars being removed by gougers (Miami News Record, July 23, 1967. The surface near the center of the collapse dropped approximately 25-feet. Four homes containing 18 persons were involved in the 1.5 acre collapse (Miami News Record, July 23, 1967). Fortunately, the collapse occurred slowly and no serious injuries occurred.

In 1968, several months after the collapse at the Netta White mine, Eagle-Picher informed residents living on four blocks above the West Netta mine, south of the collapsed area (Fig. 17), to vacate their property within thirty days (former residents-personal communication). No specific reason was given and no financial assistance was provided. The area of eviction was from "A" Street on the north to 2nd Street on the south and encompassing the west side of Vantage Street to the east side of River Street, including Frisco Street. The residents of 22 homes and three businesses were evicted from the property. A member of the Picher Mining Field Museum Board of Directors recalls the situation clearly as his mother lived at 113 S. Frisco Street (personal communication). In addition, he worked for Eagle-Picher assembling heavy equipment underground and transporting it to the Piokee mine. He recalled the instability of the roof rock in the area noting that several times the underground road under the West Netta mine was blocked by rock falls. Eagle-Picher ceased operations in the area in 1970 and deeded the abandoned land to the Ottawa Reclamation Authority. For many years the area remained vacant. Today there are several homes on the site and in 2003 the Picher Elementary School built a playground above the mine workings.

A review of the West Netta mine map shows that multiple levels of mining occurred beneath the site. For example, the 1946 and 1954 West Netta mine maps show that mining occurred on two levels beneath the area where the playground is located. Mine maps dated after 1954 no longer show the mine workings in the high upper level.

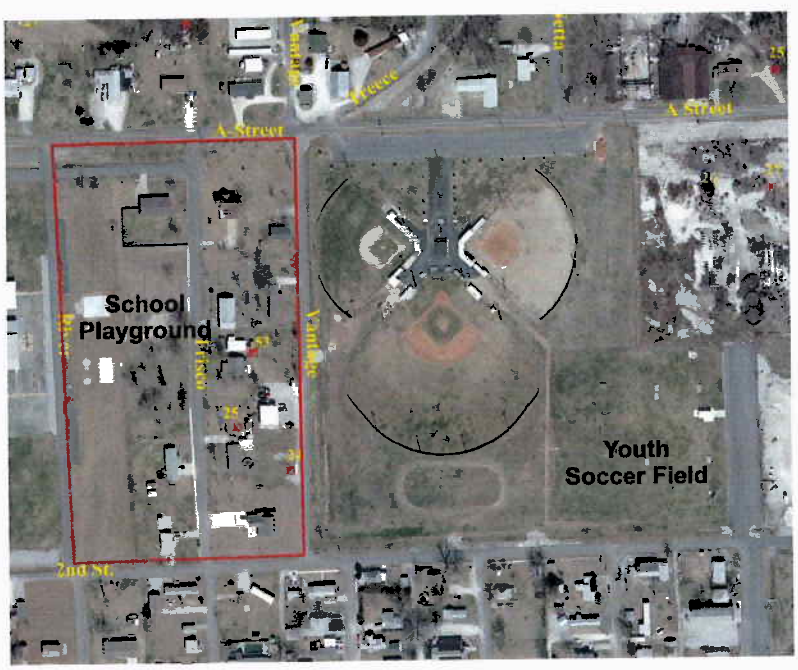

Fig. 17. Approximate area, outlined in red, that Eagle-Picher order vacated in 1968; shown are the locations of the elementary school playground and youth soccer field.

Eagle Picher also evicted residents from a one block residential area in Section 17 at the same time (former residents, personal communication). The area was bounded by "F" Street on the north, Netta Street on the west, Picher Street on the east and "D" Street on the south (former residents, personal communication).

Old Little League Ball Park

A team from the U. S. Bureau of Mines and the Geological Survey inspected the mines during August 17-31, 1967 (Westfield and Blessing, 1967). Among other recommendations their report recommended:

- That no more pillars should be removed under communities, housing, highways, roads and drainage areas-particularly Tar and Lytle Creeks, and that a team be formed to determine which pillars could be removed in the future.
- Because of excessive mining under residences, streets, secondary roads, highways, railroads, and drainage areas, an engineering study should be conducted to determine weak areas in which subsidence might occur and to recommend corrective measures for preventing public hazards.....
- A committee should be established to study requests for pillar work and to advise the Mining Supervisor of the Geological Survey whether the work should be authorized.

A committee consisting of representatives from the U. S. Bureau of Mines, U. S. Geological Survey and the Oklahoma State Mine Inspector's Office was formed in February 1968 based on the recommendation in the Westfield and Blessing report. The committee (Committee for Study of Pillar Work on Indian Lands) inspected many mines in the area over the next two years. In April 1968, the Miami office of the Bureau of Indian Affairs requested the committee to inspect the mined area beneath Block 14, including the Little League Ball Park on south Main Street in Picher. The inspection was made on April 4, 1968 and other pertinent information, including drill logs, was studied (Letter dated July 5, 1968). The Committee advised that:

- All underground mining should be restricted so that there will be no more mining in Block 14.
- There should be no permanent surface structures built on Block 14
- The area of the Little League Ball Park appeared safe at the time of this inspection; however, any crushing or removal of pillars would change this condition and the underground area will be inaccessible for inspection within the next several months.
- Playgrounds, ball parks and other park-type facilities designed for public use should be located over unmined land.

On July 15, 1968, the Superintendent of the Miami office of the Bureau of Indian Affairs revoked the city of Picher's Lease Permit granted to the Picher Little League (Certified Letter to Picher Mayor). The Mayor of Picher appealed the revocation in a letter to the U. S. Geological Survey dated September 10, 1968 citing the fact that the U. S. Geological Survey granted permission for the removal of additional pillars under the ballpark while the park was being used by the city. The Geological Survey denied the city of Picher's appeal. In 1972, the city of Picher appealed again to the Bureau of Indian Affairs for a new permit to operate the Little League Park (Fig. 18). The appeal was again denied.

The city continued to use the Little League Ball Park until 1997. In 1996 or 1997, the EPA remediated the Park including the infield and parking area due to the large amount of chat in the area. During 1997, the Environmental Protection Agency, Oklahoma Department of Environmental Quality, the City of Picher, Ottawa County, and the Ottawa County Reclamation Authority proposed a multi-purpose park facility with pavilions on the East Netta site and a sports complex on the West Netta site in Picher as a replacement for the Little League Ball Park and the Ray Harrell City Park.

In 1997, the Tulsa District of the U. S, Army Corps of Engineers (USACOE) was requested to investigate the overburden at the East Netta site for the EPA to determine if the site would be hazardous for the operation of heavy equipment, which by its vibratory nature could cause a collapse. The investigation of the site consisted of a two-fold approach (US Army Corps of Engineers, 1997); one portion of the investigation consisted of drilling borings at the site while the second consisted of consultation with a mining engineer from the U. S. Office of Surface Mining (OSM) in the Department of the Interior and a local retired mining employee who was responsible for mapping the mine workings. No drilling was conducted on the West Netta site.

The purpose of drilling was to verify an arbitrary minimum thickness of overburden remaining at four locations. In June 1997, at three locations, a three-inch hole was drilled to a depth of 100-feet using a rotary bit with fresh water mud. At each of these locations no voids were encountered. One of the drilled holes was located over the large mine void on the East Netta mine. According to the USACOE report, this indicated that no collapse structure had reached that depth. The fourth hole, north of the reunion park site, was drilled to a depth of 175-feet. From a depth of 40- to 175-feet a core bit was used to drill and provide continual core. A boring log was also prepared for the core.

Fig. 18. Ray Harrel City Park, old Little League Ball Park, and nearby chat piles on the Premier and St. Joe mine leases.

The OSM evaluation contained in the USACOE report stated that a collapse of the mining excavations was likely, but that no time frame could be predicted. The mining engineer's initial recommendation was for a systematic investigation of overburden depths in the area using a drilling unit with compressed air for lifting the cuttings. In lieu of the drilling program, he recommended a routine inspection of the ground surface in the area of potential collapse for the detection of any evidence that a collapse of the void ceiling was occurring. It is not known if another drilling program or inspection program was ever initiated.

The USACOE's conclusion stated, "Drilling activities in the time allowed indicated greater than 100-feet of overburden exists over the subsurface excavated areas at the Picher Reunion Park site, however, this investigation was limited in scope and was not able to evaluate the entire area of concern. An evaluation performed by the staff of the Office of Surface Mining (Department of the Interior) suggests that subsidence at the site is probable. Further evaluation using reflection seismic or drilling investigation to evaluate the overburden at the site would verify subsurface conditions. In lieu of further investigations, it is recommended that a quarterly visual inspection of the ground surface of the proposed park area be conducted to detect indications of subsidence. Current conditions indicate that the overburden in the area of the Reunion Park construction is sufficient to support the equipment to be used for restoration."

Since 1997 the Reunion Park has been used as the site for the annual miners reunion in Picher where between 1,000 and 1,200 visitors congregate along with a carnival, parking and venders booths. The ball park on the West Netta site is used routinely throughout the year.

On February 20, 2004, a former U.S. Geological Survey Mine Inspector in the Picher field wrote a letter to the Mayor of Picher and the Oklahoma Department of Mines expressing concern over reopening the condemned area in Picher as a public park. The former Inspector referred to his experience as a Mine Inspector in the Picher Field in the 1960s citing recent discussions with former Eagle-Picher geologists in which the geologists were "shocked" that the fence had been taken down.

Subsidence Evaluation

In June 2004, Oklahoma Senator Jim Inhofe requested that an evaluation be conducted to assess the potential for future major subsidence in the Picher Field. The USACOE was designated to be the lead agency on the subsidence evaluation project. A technical team was assembled in August 2004 to begin the subsidence evaluation. The report was released on January 31, 2006 (U. S. Army Corps of Engineers, 2006).

Two primary products were used to estimate the location, extent and magnitude of future mine subsidence in their study area. The products were: 1) exhibits that depict the location of mine workings, shaft locations, non-shaft related collapses, roof falls, and the estimated maximum subsidence from mine workings combined into on map per section and 2) figures that present the results of the analytical tool used to determine the probability of subsidence based on pre-1973 major subsidence at or adjacent to major transportation corridors, residences and structures. The probability analysis was recommended as a tool to prioritize areas for further evaluation and mitigation.

Estimated maximum subsidence was defined for their study as the maximum amount of subsidence (measured in feet) that could occur at a given surface location as a result of collapse of mine workings. This value was calculated based on the height of the mine workings and bulking factors for the geologic units over the mine workings.

A total of 286 numbered locations in their study area were predicted to have some degree of subsidence if the mine workings were to collapse. Three public use areas (parks and playgrounds), Reunion Park, a youth soccer field, and a grade school playground, were identified as areas of concern on the East and West Netta mines. Reunion Park had an estimated maximum subsidence of greater than 50 ft (Fig. 19). The grade school playground (Fig. 20) and the youth soccer field had an estimated maximum subsidence from 25 to 50 ft.

The Picher-Cardin school board and Picher city officials were briefed about these areas. The following three options were presented: 1) close/relocate the facility, 2) conduct a site-specific evaluation followed by geotechnical evaluation, and/or perform regular monitoring using visual and/or geotechnical methods. The costs of the evaluation, and possible long-term monitoring should be determined. The benefits of continuing to use these facilities should be evaluated against the risk and overall cost of closure/relocation, the geotechnical evaluation, and long-term monitoring. Picher city officials closed and fenced Reunion Park. The school board closed the school playground when school was in session.

The report recommended that locations where residents were previously evicted by the Eagle-Picher Mining & Smelting Company and public use areas that were restricted by Eagle-Picher and BIA because of the potential for subsidence should be further evaluated prior to development of public use facilities or expansion of residential areas. This includes the old Little League Ball Park and the Ray Harrell City Park.

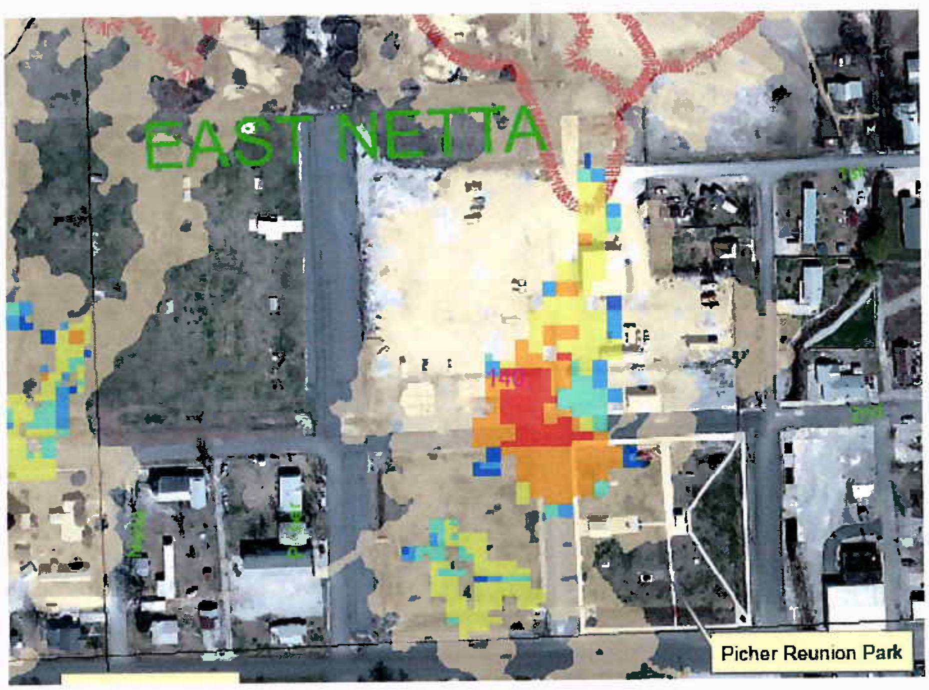

Fig. 19. Maximum estimated subsidence of greater than 50 ft (shown in red) in Reunion Park.

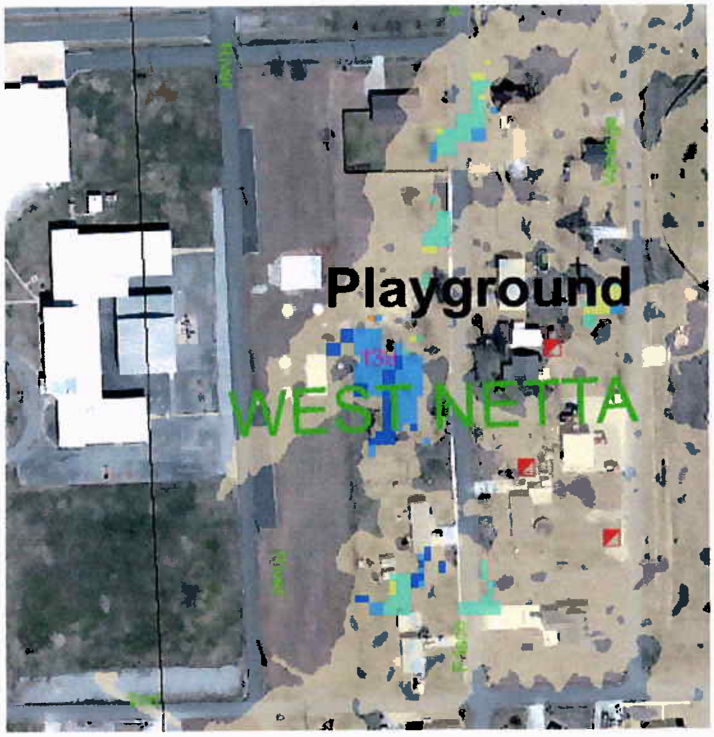

Fig. 20. Maximum estimated subsidence of 2 to 5 ft (shown in blue) at the elementary school playground and 25 to 50 ft (shown in orange, one pixel).

STOP 2. TAR CREEK AT DOUTHAT ROAD BRIDGE

Introduction

Tar Creek is the principal drainage system in the Picher Field. With its headwaters in Cherokee County, Kansas, Tar Creek flows southerly through the field between Picher and Cardin, passing Commerce and Miami on the east, to its confluence with the Neosho River. Tar Creek is a small ephemeral stream characterized by standing pools. With its major tributary Lytle Creek, Tar Creek drains approximately 53 sq mi.

Iron and other sulfides present in drifts, stopes, and pillars were exposed to atmospheric oxygen during mining. Water in the mines rose steadily when pumping was discontinued in 1970. Upon contact with water, the oxidized sulfides readily dissolved and produced acid mine water. This resulted in the dissolution of insoluble metal sulfides such as galena and sphalerite and further liberation of heavy metals.

In September 1975, the USGS began monitoring water levels in a well on the Blue Goose No. 2 mine lease, 1.5 miles northeast of Commerce, Oklahoma, SE¼, SW¼, sec. 30, T. 29 N., R. 23 E. The water level in the well rose at an average rate of 2.6 ft per month from September 1975 to February 1980. In November 1979, surface discharge of acid-mine water took place near Commerce, Oklahoma (NW¼, NW¼, SE¼, sec. 7, T. 28 N., R. 23 E; ½ mile west of Tar Creek), at approximately 790 feet above mean sea level (MSL). Mine water continues to discharge at this location. In 2002, water-level measurements at 20 ground-water and 9 surface-water sites within the mining district indicated that the water table is relatively flat at approximately 800 ft above NAVD (North America Vertical Datum) 88 in the mining district (DeHay and others, 2004). Other principal discharge points of mine water into Tar Creek occur up stream from the bridge for about a quarter of mile in the old Ltyle Creek drainage and southeast of the bridge for about a quarter of a mile.

In 1980, the Governor of Oklahoma formed the Tar Creek Task Force, comprised of 24 local, state, and federal agencies, to investigate the effects of acid mine drainage on the area's surface and ground water supplies. The Task Force investigated the problem in 1980 and 1981 with the assistance of Hittman and Associates, Inc. Based upon the information discovered by the Task Force, EPA proposed, in July 1981, to add the Site to the Superfund National Priorities List (NPL). The site was listed on the NPL on September 8, 1983.

Operable Unit 1 (OU1) response actions at the Site were conducted as a State-lead project, with the EPA acting as the support agency. The lead State technical agency for the Site was the Oklahoma Water Resources Board (OWRB), and the lead State administrative agency was the Oklahoma State Department of Health (OSDH). On July 1, 1993, State responsibility for all aspects of the project was consolidated when the project was transferred to the newly created ODEQ. ODEQ remains the lead agency for activities at the site.

The EPA issued its first Record of Decision (ROD) for the Site on June 6, 1984. The ROD addressed two concerns: 1) the surface water degradation of Tar Creek by discharge of acid mine water; and 2) the threat of contamination of the Roubidoux aquifer, the regional water supply, by downward migration of acid mine water from the overlying Boone aquifer through abandoned wells connecting the two.

The 1984 ROD called for the elimination or reduction of the discharge of mine water by reducing surface recharge into the mine workings. In 1986, dike and diversion structures were completed at the Muncie and Big John mines in Kansas, around the south end of the Admiralty No. 1 collapse, and Lytle Creek (Fig. 21) was diverted from the old railroad bridge to its present location. At that time, these sites were thought to represent approximately 75 percent of the total inflow into the mines. The dike and diversion structures did reduce the temporary rise in water levels in the mines that occurred in response to a given rainfall event. However, the average water level in the mines was not lowered significantly after the remedy was constructed. The volume of acid mine water discharging from the mines into Tar Creek was not significantly different from the amount of water that was discharging before the remedy was constructed. Therefore, dike and diversion did not significantly reduce the surface discharges of acid mine water.

The 1984 ROD called for preventing the downward migration of mine water into the Roubidoux Aquifer by plugging 66 abandoned wells. During remediation, an additional 17 wells were identified and plugged, bringing the total to 83 wells. The dike and diversion and well-plugging programs were completed in December 22, 1986.

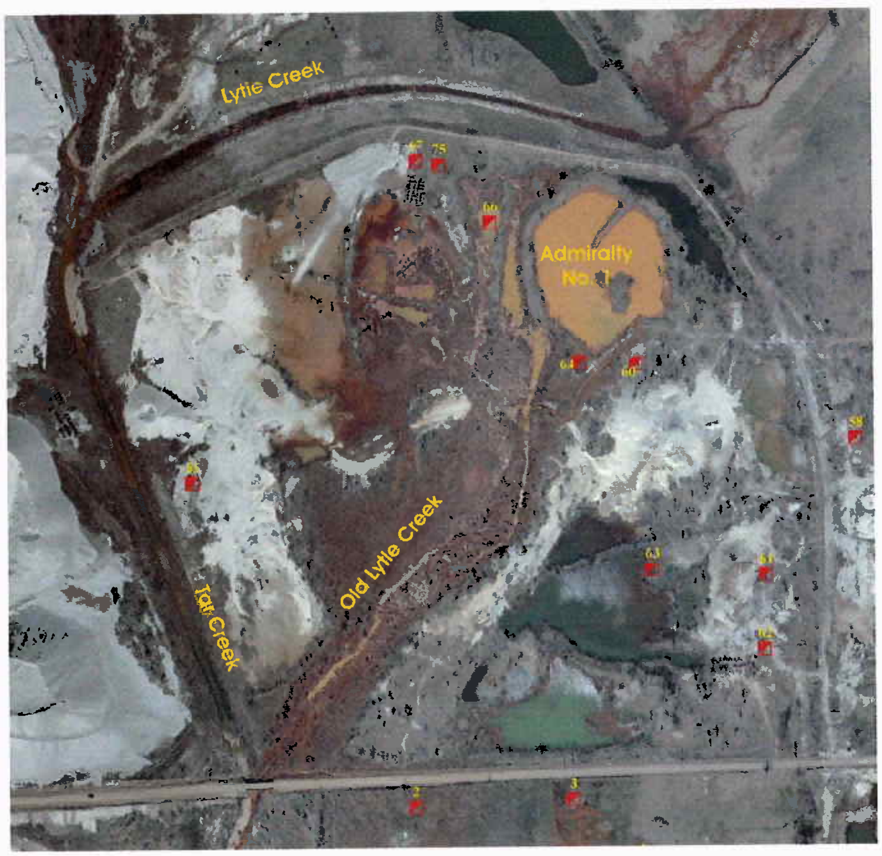

Fig. 21. Diversion of Lytle Creek and breeched dike on the southeast end of the Admiralty No. 1 collapse; red boxes represent mine shafts.

Ground-Water Quality in the Mine Workings

A 1976-1977 study of the ground-water quality in the Boone aquifer through sampling of open mine shafts, concluded that water quality was stratified in mined voids, with specific conductance, dissolved solids, sulfate, and metals increasing and pH decreasing with depth (Playton and others, 1980). Greater concentrations of most metals in water in the mineshafts compared to other parts of the Boone aquifer and increasing concentrations of metals with depth indicate that there was a substantial quantity of dissolved metals in ground water in the mining district. Playton and others (1980) reported that water in seven mineshafts in the Picher Field was not uniform with depth. The mines were sampled multiple times over the course of a year and no areal or seasonal variation in water quality was reported. The mine water was stratified. Specific conductance and water temperature tended to increase and pH tended to decrease with depth. Dissolved solids concentrations and chemical constituents, such as total and dissolved metals and dissolved sulfate, increased with depth.

In 2002, the USGS in cooperation with the ODEQ sampled seven mineshafts in the Picher Field (DeHay, 2003). The purpose of this study was to determine how the water quality in the Boone aquifer had changed with time. Attempts were made to sample the same sites sampled in 1976-77, but many of these sites were no longer accessible, so alternate sites were selected as near as possible to the sites sampled in 1976-1977.

Vertical profiles of specific conductance, pH, water temperature, and dissolved-oxygen concentrations were collected from each mineshaft. The increases in specific conductance were typically gradual until the last 20-40 ft of the sampling column below which substantial increases were measured. In individual mineshafts the pH values were generally consistent within the top of the water column. Lesser pH values were measured at the base of some mineshafts, and at the water surface in some of the mineshafts that had debris on the surface. Water temperatures generally decreased with depth in the mineshafts, though a slight increase in temperature was measured at the very bottom of some shafts.

In 2002, concentrations of major ions and metals varied between the mineshafts and with depth. Most concentrations of metals and ions were consistent through the shafts. Some of the mineshafts had an increase in metals concentrations in the last 20-40 ft of the sampling column in the mineshaft. Increases in metals concentrations at the bottom of those shafts could indicate the quality of the water in the mine rooms rather than in the shafts.

Greater concentrations of iron, manganese, nickel, and zinc were detected in the mineshafts that had less dissolved oxygen in the water. These metals precipitated out of solution to form oxide minerals when in the presence of oxygen in the water. Also, in samples with large concentrations of those metals, concentrations of lead and cadmium tended to be greater near the water surface than at the bottom of some mineshafts.

The concentrations of mine-water constituents were greater in 1976-77 than 2002 data (Table 2). Specific conductance in 2002 samples was less than in 1976-77 data fall in a much greater range. Concentrations of metals, except copper, from water samples collected from the mineshafts in 2002 were significantly less than concentrations of metals from samples in 1976-77.

Many of the metals sampled in the 2002 study are regulated by the EPA to protect human health and the environment. EPA (2002) established National Primary Drinking Water

Table 2. Comparison of some water properties, major ions, and trace elements (50 percentile) for water samples collected in 1976-1977 and 2002 from mineshafts (modified from DeHay, 2003)

Constituents/Water Properties	1976-1977 Data	2002 Data
Specific conductance (µS/cm at 25°C)	2,850	1,180
pH, field (standard units)	6.4	6.3
Hardness, total (mg/L)	1,800	500
Alkalinity, lab (mg/L as $CaCO_3$)	29	88
Dissolved solids (mg/L, residue at 180°C)	3,130	761
Calcium (mg/L)	480	152
Magnesium (mg/L)	130	28
Sodium (mg/L)	44	17
Potassium (mg/L)	3.8	2
Sulfate (mg/L)	2,100	414
Aluminum (µg/L)	600	<1
Arsenic (µg/L)	1	<2
Cadmium (µg/L)	80	8
Copper (µg/L)	8	9
Iron (µg/L)	46,000	22
Lead (µg/L)	69	1
Nickel (µg/L)	700	25
Maganese (µg/L)	1,900	375
Zinc (µg/L)	120,000	2,140

µS/cm at 25°C, microsemens per centimeter; degrees Celsius
mg/L, milligrams per liter
µg/L, micrograms per liter
<less than; below detection limit

Regulations to protect human health and National Secondary Drinking Water Standards to maintain the aesthetic quality (odor, taste, color) of water.

The primary regulation for cadmium, 5 µg/L, was exceeded in over 50 percent of the 2002 samples. The secondary standards for iron, 300 µg/L, nickel, 100 µg/L, and zinc, 5,000 µg/L, were exceeded in over 25 percent of the samples and the secondary standard of 50 µg/L for manganese was exceeded in almost 75 percent of the samples. Lead did not exceed the primary regulation of 15 µg/L; however, is not readily soluble in most water.

Surface-Water Quality

The water quality in Tar Creek is adversely impacted by mine water discharging from drill holes, mine shafts, collapse features, leachate from chat piles and run-off from former tailings ponds. The OWRB sampled 11 stream and three mine discharge sites (Figs. 22-23; Table 3) in 1981-1982 (Oklahoma Water Resources Board, 1983). Some of their data is summarized in Tables 4 and 5. Zinc, cadmium, and lead for site 4S were significantly higher than concentrations a site 14. No published data was found to determine what, if any, changes have occurred since the 1981-1982 data was collected. However, the water quality in the mines in the main part of the Picher field has improved since 1977-1978 (DeHay, 2003)

Chat and former tailings ponds produce leachate, which contains cadmium, iron, lead, and zinc, that enters Tar and Lytle Creeks. A segment of Tar Creek was selected the USGS to characterize and quantify metal loadings by leachate from the Admiralty No. 4/Douthat chat pile west and adjacent to Tar Creek. A former tailings pond is located on the east side of Tar Creek in this area. Four surface-water sample sites along the study segment were sampled seven times over 14 days following a rainfall event. Instantaneous loads of cadmium, iron, lead, and zinc were determined for each sample. Iron and zinc loads were much greater than cadmium and lead loads in both leachate and mine discharge. Mine discharge water contained more iron than the chat leachate. Cadmium loading from chat leachate was greater than cadmium loading from mine discharge within the study segment. Zinc and lead loadings from mine discharge were comparable to zinc and lead loadings from chat leachate at the study segment except during the first day following the rainfall event (Cope and others, 2006). A similar study was conducted by Schaider and others (2006) near the USGS study segment. Their data was collected when Tar Creek had normal and/or low flow rates. The chat piles contributed the majority of cadmium and lead to the creek and substantial portion of zinc. Water discharging form the mines contributed most of the iron and zinc to the creek.

The Spring and Neosho Rivers carry water from the mining district directly into Grand Lake O' the Cherokees, raising concerns about the water quality and aquatic life of Grand Lake. The United States Geological Survey, in cooperation with the Oklahoma Department of Environmental Quality, the Seneca-Cayuga Tribe and the Wyandotte Nation, collected high flow water-quality and bed sediment data from Tar Creek, Spring River, and Neosho River to characterize water and sediment quality entering Grand Lake O' the Cherokees. Water samples were analyzed for physical properties, major ions, and dissolved and total metals. Sediment samples were analyzed for metals only. Unfiltered water-quality samples contained concentrations of lead ranging from less than 10 to 152 µg/L and zinc concentrations ranging from 7 to 3,100 µg/L. Cadmium concentrations were below detectable limits in most of the samples collected from the Spring and Neosho River sites, but ranged from less than 5 to 15 µg/L at the Tar Creek sites. Bed sediment samples contained larger concentrations of aluminum,

Fig. 22. Mine water discharging from a drill hole in 1980 at Commerce, Oklahoma; near OWRB sample site 14.

Fig. 23. Mine water discharging into Lytle Creek from drill holes, mine shafts, and collapse on the Admiralty No. 1 Mine in October, 1981; near OWRB sample site 4S.

Table 3. Description of 1981-82 OWRB sample sites (Oklahoma Water Resources Board, 1983).

Site	Stream and Mine Discharge Site Descriptions
7	Tar Creek, on the Oklahoma-Kansas state line immediately south of the low water bridge.
4a	Tar Creek, 20 yards upstream of the Lytle-Tar Creek Confluence.
4	Tar Creek 50 yards downstream from the Lytle-Tar Creek confluence. This site receives sewage discharge from the Picher treatment facility via Lytle Creek.
10	Tar Creek below US Highway 66-69 bridge near Commerce. This site is one mile south of site 4 and receives additional flow from an unnamed tributary which flows along the southern edge of the mine field.
14b	Tar Creek approximately 100 yards below confluence of stream from site 14 spring discharge and site 13 subsidence discharge. The flow at this point consists of discharge from the Commerce sewage treatment plant, Garret Creek, and sites 13 and 14.
20	Tar Creek one mile from the Neosho River. A USGS hourly monitoring station was located here.
22	Tar Creek, approximately 300 yards upstream from the confluence with Neosho River. This portion of Tar Creek is slow moving and highly diluted from water backed up by the Grand Lake reservoir.
22a	Neosho River, approximately 300 yards upstream from the confluence with Tar Creek. This site was a control to measure the effects of Tar Creek on the Neosho River.
22b	Neosho River, Approximately 300 yards downstream from the confluence with Tar Creek, just past the I-44 bridge.
23	Spring River at State Highway 10.
24	Spring River, approximately 100 yards north of Twin Bridges.
4S	Mine discharge from two bore holes approximately 40 yards east of the confluence of Tar Creek and Lytle Creek.
13	Mine discharge from a large subsidence pit filled with mine water located in southwest Commerce. This flow combines with that from site 14 before entering Tar Creek one mile away.
14	Mine discharge from a drill hole just south of Commerce and about 100 years east of US Highway 66-69.

iron, zinc and manganese than other constituents. Lead concentrations in the samples ranged from less than 10 mg/L per kg to 262 mg/L per kg. Fourteen sediment cores were also collected from the Tar Creek floodplain at Tar Creek near 22nd Street Bridge, Miami, OK. All of the core samples had detectable concentration of aluminum, barium, chromium, copper, iron, lead, magnesium, manganese, nickel and zinc. Twelve sediment cores had mean lead concentrations of 15 to 29 milligrams per kilogram but two cores, collected near a slough on the west side of Tar Creek, had mean lead concentrations of 147 and 518 mg/L per kg (DeHay, 2006).

Table 4. Summary of stream water quality data (mean values) Collected by the Oklahoma Water Resources Board in 1981-1982 (Oklahoma Water Resources Board, 1983)

Site Number	Specific conductance (μmhos/cm)	pH (standard units)	DO (mg/L)	Iron (μg/L)	Zinc (μg/L)	Cadmium (μg/L)	Lead (μg/L)	Chromium (μg/L)	Fluoride (mg/L)
7	1,249	6.5	4.1	7,871	6,493	17.6	71.8	<10	0.29
4a	1,484	6.2	4.7	12,020	27,398	24.0	23.0	<10	0.90
4	2,136	5.7	3.9	53,751	38,644	56.0	171.0	11.6	2.90
10	1,981	5.7	4.9	27,137	37,247	32.0	92.0	13.5	2.90
14b	2,402	4.1	2.3	53,450	87,250	43.0	26.7	<10	3.15
20	1,554	5.4	6.0	8,853	21,333	18.6	33.0	18.0	2.15
22	829	6.5	4.7	1,278	4,582	4.0	<20	<10	0.60
22a	380	7.1	4.1	1,703	485	2.7	<20	<10	0.30
22b	396	7.2	5.7	1,083	325	2.1	<20	<10	0.26
23	257	6.8	5.4	1,430	161	<2.0	<20	<10	<.10
24	244	6.7	4.7	2,100	238	<2.0	27.0	<10	<.10

mg/L, milligrams per liter
μg/L, micrograms per liter
<less than; below detection limit

Table 5. Summary of mine discharge water quality data (mean values) collected by the Oklahoma Water Resources Board in 1981-1982 (Oklahoma Water Resources Board, 1983)

Site Number	Specific conductance (μmhos/cm)	pH (standard units)	DO (mg/L)	Iron (μg/L)	Zinc (μg/L)	Cadmium (μg/L)	Lead (μg/L)	Chromium (μg/L)	Fluoride (mg/L)
4S	4,236	4.9	0.53	355,833	228,061	135.0	60.0	8.2	13.70
13	3,659	2.5	3.50	109,750	88,750	362.0	199.0	14.0	6.60
14	4,278	5.6	0.60	530,000	145,105	14.0	20.2	10.2	4.80

mg/L, milligrams per liter
μg/L, micrograms per liter
<less than; below detection limit

STOP 2A. CHAT PROCESSING PLANT AND CENTRAL MILL TAILINGS PONDS

Significant quantities of mill-waste material were generated by milling of the lead-zinc ores. Approximately 7,000 surface acres were affected by mine- and mill-waste materials. The discarded mill-waste material, chiefly composed of chert fragments 0.75 in. or less in diameter, was referred to as *chat*. The chat was transferred away from a mill by a series of conveyors and elevators and heaped into piles. Some piles attained heights greater than 200 ft. Prior to 1930, almost every mine had its own mill. Therefore, large areas of land previously used for agriculture were used to store mill waste. Ore recovery prior to 1920 was 58-70%. New advances in extraction metallurgy encouraged mine owners to reprocess the tailings. In some instances tailings were reprocessed a third time for their lead and zinc content.

Some of the larger chat piles are being reworked for a final time. The material was processed for railroad ballast, road building, and concrete and asphalt aggregate. The material is now utilized as an aggregate in asphalt.

North of the road, Flint Rock is working the Admiralty No. 4/Douthat chat pile for asphalt aggregate. The chat is dumped into a hopper and transport to the plant by a conveyor. The chat is washed and screened to produce at least two products at this location. They are a -3/16 in. or manufactured sand and 3/8-in. chip (Fig 24). The fines are pumped to a former tailings pond west of the plant (Fig. 25).

Fig. 24. Flint Rock's chat processing plant at the Admiralty No. 4 chat pile.

Fig. 25. Fines generated from washing chat are discharged into a former tailings pond.

Two of largest tailings ponds in the mining district are located north and south of the road. The north pond was about 80 acres and the south pond was about 140 acres (Fig. 26). Both ponds were associated with Eagle Picher's central mill located about a ¼ of mile southwest of this location. The 1930's witnessed the growth of central milling in the field. The first mill built to treat ore from several tracts was the Bird Dog Mill of the Commerce Mining & Royalty Co., completed in 1930. This plant was designed to process 2,750 tons/day on a 24-hr basis. The sampling and milling of ores from several different tracts proved economically feasible. The milling practice up to that time (largely at the landowner's and royalty owner's insistence) was to have separate mills on each 40- or 80-acre lease to ensure proper royalty distribution. In 1932, Eagle Picher completed their central mill. The initial capacity, rated at 3,600 tons, was shortly increased to 5,500 tons and later to 10,000 tons/day, with an ultimate capacity of 18,000 tons/day.

Air borne dust particles that originate from mill tailings ponds and disturbed chat piles may pose a potential risk to human health in the area (Fig. 27). A study by Datin and Cates (2002) found that chat piles contain high concentrations of metals (Pb, Cd, Zn) in the finer sized material relative to background soils. The minus #40 sieve (‹0.425 mm) represented a break point where the concentrations of lead, zinc, and cadmium begin to rapidly increase with decreasing particle size.

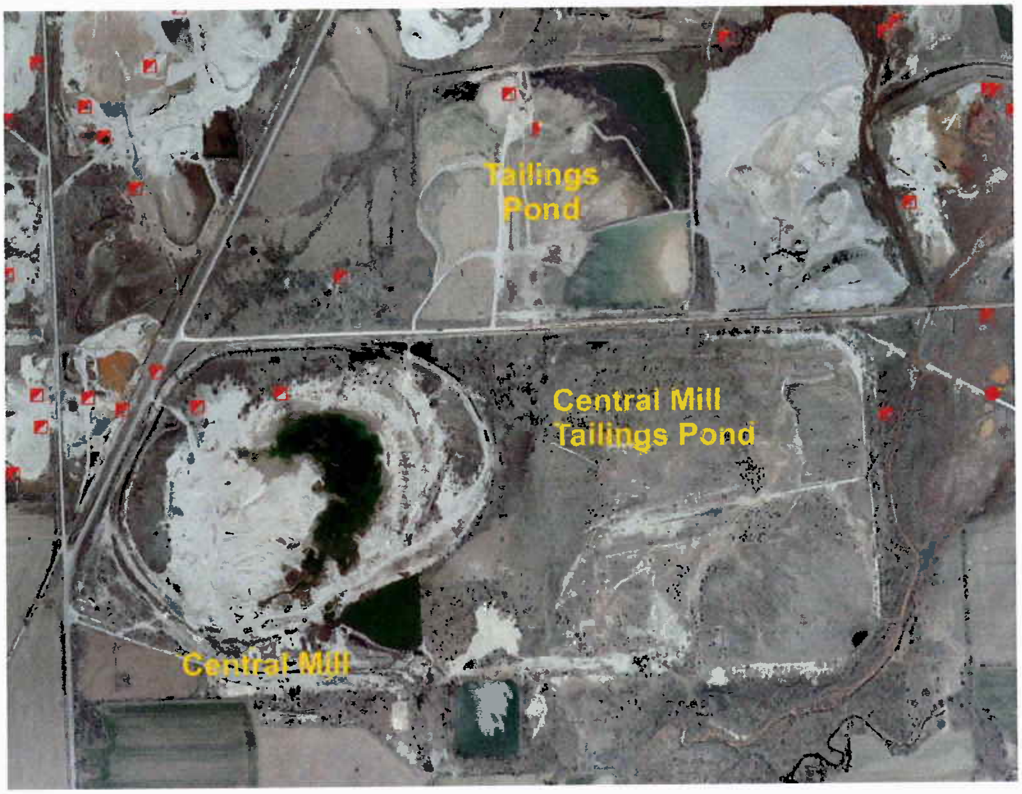

Fig. 26. Tailings ponds associated with Eagle-Picher's central mill.

Fig. 27. Wind is blowing fine chat particles across the road from a chat aggregate plant.

STOP 3. DOUTHAT (CENTURY), OKLAHOMA

Douthat

Douthat is located two miles south of Picher. It was established in 1917 and named for Zahn A. Douthat, the townsite owner (Fig 28). The 1917-1918 business directory for Century, Oklahoma, lists 4 barber shops, Lucky Kid, Poolers Place, M. M. Cline Barber Shop, and City Barber Shop, Century Garage, Sargeant & Gray livery, a feed barn, Lyric Theater, several grocery stores, Aten shoe shop, Priar the Tailor, and one physician, Everett Lewis. Century had two hotels, Shannon Hotel and Depee Hotel, and 4 major building and lumber companies, Coyne Lumber Co. (branch of Webb City, Missouri), A. Hood & Sons (branch of Pittsburg, Kansas), Home Building and Lumber Co., and C. E. Matthews Lumber Co. A. Hood and Sons sold auto accessories, carpets, rugs, furniture, hardware, harness, mining supplies, paints, oil, and varnishes, stoves, and victrolas. Coyne Lumber Co. sold building materials such as cement, lumber, mining and mill timbers, specialty molding, roofing paper, sash, and doors. In 1917, the Century Café, Mack's Café, Century Chili Parlor, and the Owl Café were some of the places to dine out in Century, Oklahoma.

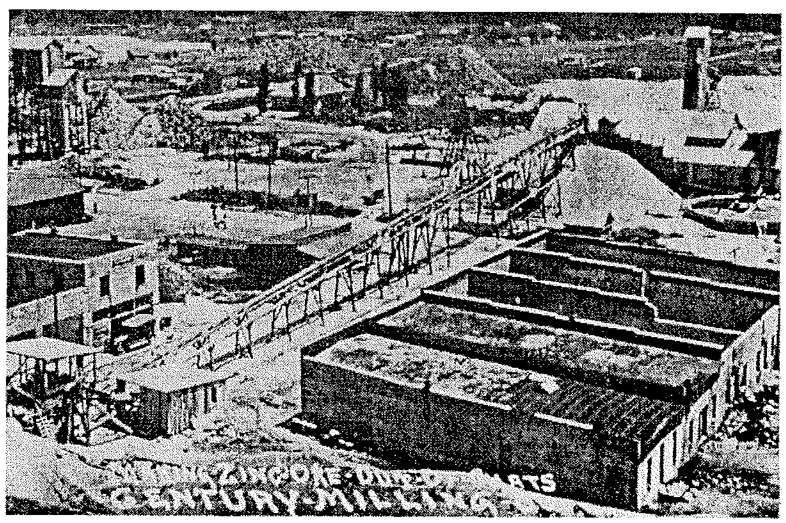

Fig 28. Douthat (foreground) looking south towards the Montreal mill. The photograph was taken from the Admiralty No. 3 chat pile that was south of the mill.

Admiralty No. 3 Mill And Mine

Introduction

. The Quapaw Indians, who were originally from Ohio, were given 150 sections of land in southeastern Kansas and northeastern Oklahoma (Indian Territory) in 1833. In 1867, the Quapaws were forced to give up their lands in Kansas. Although land ownership in Oklahoma originally was vested with the Quapaw tribe, an allotment plan approved in 1893-94 divided the reservation into 236 200-acre allotments and 231 40-acre allotments (Stroup and Stroud, 1967).

The size of most mining tracts was 40 acres or some multiple of 40 acres, such as 80 or 160 acres. Some tracts, particularly in the earliest-worked fringe, were subdivided into areas of 10 acres of less. The orebodies were nearly flat, and the operators mined to the vertical planes that marked the extension of the land boundaries at depth. Mining rights were nearly flat, and the operators mined to the vertical planes that marked the extension of the land boundaries at depth. Mining rights were leased from the landowners, who were paid a percentage royalty of the gross mineral sales from the tract. In Oklahoma, most land ownership was originally vested in individuals of the Quapaw Indian tribe. A common practice in the history of the field was for the holder of the first lease—whether an individual, royalty company, or mining company—to sublease at an increased royalty rate to the actual operator or middleman.

Because of the shallowness of the deposits, the relative ease with which they could be mined and milled, and the wide technical experience gained from earlier operations in adjacent subdistricts of the Tri-State region, numerous small but efficient mining companies were organized for operation on individual 40-acre tracts. A large turnover in operating companies occurred from year to year. Leases changed hands or were subdivided or regrouped into different operations and mine names were constantly changing. Orebodies commonly extended from one tract to the next.

Admiralty Mines

Admiralty Zinc Company was operating the Admiralty Nos. 1-4 near Century in 1917. The Admiralty mines were located on 160 acres and were part of the Zahn A. Douthat's Quapaw Allotment. These mines were located in T29N, R23E, sec. 29 (Fig. 29). In 1948 the Nellie B Mining Company acquired these properties along with the Skelton, Lawyers, Rialto, and Barbara J properties. Nellie B Mining Company operated on this property from 1948 to 1951. On September 19, 1951 American Zinc, Lead, and Smelting Company acquired the Nellie B property by purchasing the stock of the Nellie B Mining Company. In addition to the mining leases, the acquisition included all mills, mining equipment, and other facilities on the allotments and an extensive chat sales operation.

Admiralty No. 3 Mill Site

At this mill site there are two shafts, nos. 57 (mill) and 58 (field) (Figs. 29-30), about 165 ft apart. All orebodies in the Oklahoma portion of the Picher were intersected by vertical shafts usually having but one compartment. Shaft dimensions were commonly 5 x 7 ft or 6 x 6 ft in cross section. Most shafts were sunk 5-12 ft below the level of the orebodies to provide a drainage sump. A platform was constructed over the sump to permit handling of the ore buckets. From the collar down to a point below the shale, the shaft was close-cribbed with 2- x 6-in. pine timbers. Lagging, which was placed behind the cribbing, secured the cribbing and prevented misalignment. A common practice was to crib the shaft through the first shale zone unless deeper shale or broken strata were encountered. However, a number of shafts were continuously cribbed to guard against the possibility of hanging the bucket on the wall or overturning in the shaft. Men were raised or lowered in buckets, and machinery and supplies were handled either in buckets or with cables (Weidman and others, 1932).

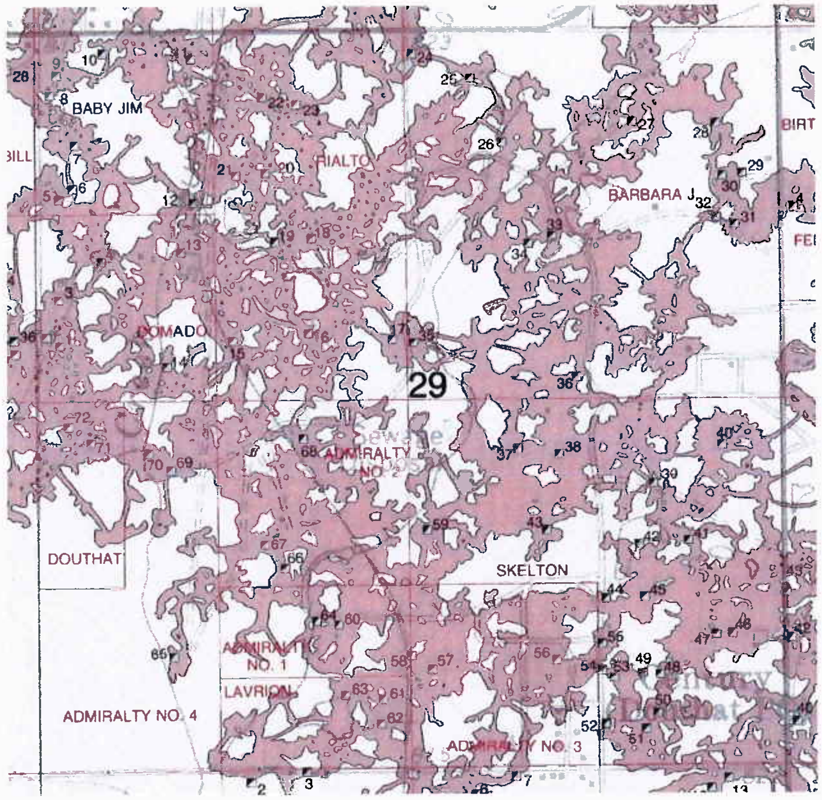

Fig. 29. Location of the Admiralty leases in sec. 29. Shaft no. 57 is the mill shaft on the Admiralty No. 3 lease and shaft no. 58 is the field shaft.

Fig. 30. Admiralty No. 3 field shaft (no. 58) was a 5 x 7 ft, open concrete cribbed shaft in 2004.

Generally in the initial stages of mine development, an auxiliary shaft or field shaft was sunk about 100-300 ft from the first shaft. The first shaft usually was used to lift ore up to the surface for processing at a nearby mill. The two shafts were connected by a drift to improve ventilation and/or to provide an alternate route for egress. At this site, the mill shaft and the field shaft are 165 ft apart.

Mining was done by a random room-and-pillar method. Rooms or open stopes were created with irregularly space pillars. The structure and lithology in the roof or *back* of the stope and the width and height of the orebody controlled the size and spacing of the pillars. If the shaft was completed in the orebody, stopes were opened radially from the shaft to the full height of the ore. Pillars, 20-50 ft in diameter are commonly spaced 30-100 ft apart, supported the back. The minimum height of the working face was about 6 ft, the average about 25 ft, and the maximum was more than 100 ft. About 15% of the orebody was initially left for the pillars. Later, when the reserves were depleted, as much as 50% of the tonnage left in the pillars was recovered by slabbing operations or by complete removal of certain pillars (Weidman and others, 1932).

The mill shaft is at an elevation of 828 ft. Three main levels were developed on this lease. The deepest level, which was at 203 to 227 feet below the surface, was developed in the vicinity of the mill. Lower level stopes were 400 to 800 feet wide, and heights ranged from 10 to 33 feet. The M bed was mainly mined in the lower level workings. Upper and middle level stopes were developed mostly in the northeast part of the lease. The middle level workings were at 172 to 198 ft and the upper level was at 77 to 92 ft below the surface. Middle level stopes varied from 100 to 400 ft wide; heights ranged from 16 to 32 ft. The main ore horizon mined in the middle level was the G-H bed. Upper level workings, which overlie the middle level, had stope widths that varied from 150 to 200 feet and heights that ranged from 12 to 23 feet and higher. Many of the upper level stopes are caved to the surface.

The Batesville Sandstone crops out near and southeast of the mill shaft. In the vicinity of the upper-level stope, there is about 20 feet of alluvium, mostly clay, which overlies a 20-ft thick limestone. Below the limestone is 30 ft of shale and "boulders."

Milling is the process whereby the metal values contained in the mined crude ore are concentrated to produce a saleable product or concentrates. The concentrates, usually 80 percent for lead and 60 percent for zinc, were sold to various smelting companies. The smelting companies purchased the concentrates from the various active mills and transported this material to their smelters for refining.

The basic milling practice used in the Tri-State District was gravity and/or mechanical concentration. Gravity concentration, as developed in the district, utilized jigging and tabling to remove the gangue minerals and chert from zinc and lead sulfides. The gravity concentration practices used in Ottawa County were developed in the Missouri portion of the district, with the jigs, tables, and other milling equipment manufactured in Joplin, Missouri. These gravity mills were commonly known as Joplin-type mills. They typically had the capacity to process from 25 to 30 tons of ore per hour and normally operated for 10 hours per day.

The first step of the milling process was to reduce the fragments of crude ore to jig size (3/8 to 5/8 in.) in the crushing circuit. Crushing was typically done with a Blake-type jaw crusher located on the tallest pillar next to the mill. This material was further crushed by breaker and secondary roller crushers. Crushing of the ore was normally done wet. After the crushed ore was screened and the fines removed (deslimed), the sized ore was fed to the primary gravity concentration circuit.

Primary gravity concentration was accomplished with jigs. The jigs consisted of several compartments of hutches where the sized ore was agitated in water causing the lead and zinc materials with higher specific gravity to be separated from the waste rock. Typically the primary concentration circuit used one or more primary and secondary jigs. This process produced four primary products: zinc concentrates, lead concentrates, middlings, and tailings. The zinc and lead concentrates were deposited in separate storage bins for future sale, the middlings were directed to the secondary concentration circuit, and the course tailings (known as chat) which typically made up about 80 percent of the mill feed, were dewatered and deslimed and than transported to waste piles immediately adjacent to the mill by means of tailings elevators or a belt conveyor.

In the secondary gravity concentration circuit, the middlings were reground to sand-sized particles by means of roller crushers to liberate more of the contained zinc and lead. This sized material was retreated by both jigs and tables or by tables only in what was known as the sludge mill. Tables are lightly tilted flat surfaces over which ground ore is passed in a slurry with water and the lead and zinc particles with higher specific gravity are separated form the other solid materials. The number of tables used in a mill varied, but typically 8 to 9 tables were used until flotation was introduced in the 1920s. The secondary concentration circuit produced three primary products: zinc concentrates, lead concentrates, and tailings. The lead and zinc concentrates were usually combined with the lead and zinc jig concentrates. The sand-sized tailings were typically disposed with the course jig tailings (chat).

In the Picher Field, the crude ore contained a larger percentage of finely disseminated zinc minerals. The Joplin mills could only recover up to 50 percent of the zinc. The zinc losses were somewhat reduced in the early 1920s by increasing the number of tables in the secondary concentration circuit. Recoveries remained relatively low until flotation circuits were added to the mills to treat the fines (slimes) generated during the milling process.

Flotation is a process where mineral particles are selectively made to attach to air bubbles by means of chemicals and then the minerals are collected as a mineral-laden froth from the surface. Flotation was tried experimentally in the Tri-State District beginning in about 1916, but was not used to any extent in the mills until about 1924. By 1931 most mills in the Picher Field had a flotation circuit. The early flotation process only worked on fine particles. The principal fraction floated in the district was the fines from the crushing and gravity concentration circuits. Some mills ground all or part of the middlings from the jig circuit for their flotation circuit.

Flotation provided for the recovery of the zinc that was contained in the fines and lost to the tailings by the early operations. Average zinc recoveries from the mills in the Picher Field increased to about 80 percent with the addition of flotation circuits. Flotation did not have a significant effect on lead recoveries, as about 90 percent of the lead was recovered by gravity. The flotation circuit produced three products: zinc concentrates, lead concentrates, and tailings. The tailings were typically pumped as a slurry to a bermed tailings pond. Some mills pumped flotation tailings to the top of the gravity concentration tailings (chat) piles (Fig. 31).

The Admiralty No. 3 mill was fully operational in 1917 (Sandborn Map Company, 1917). The mill, which is oriented northeast-southwest, had its primary crusher on the northeast end on top of the largest pillar near the mill. The jig mill had 2 jigs and 13 cells. The sludge mill, which was located on the southwest end of the mill, had 6 tables. The ore bins were located on the northeast end of the mill. By 1928, the mill had added a Dorr thickener, large, concrete circular tank, and a flotation mill on the southwest end of the mill (Sandborn Map Company, 1928). The mill had to be expanded to accommodate the flotation mill (Fig. 32). The tailings pile was

Fig. 31. Flotation tailings on top of chat at the Admiralty No. 1 Mine.

Fig. 32. New piers added to the old mill for the flotation circuit.

STOP 3A. ADMIRALTY NO. 1 COLLAPSES

The Admiralty No. 1 is on a 20 acre lease operated by Admiralty Zinc Co. in 1917. The mill had 2 jigs and 11 cells in the jig mill and 4 tables in the sludge mill. They used an elevated tramway to convey the ore from the field shaft (shaft no. 64, Fig. 2) to the mill. By 1928, the mill was dismantled.

Three ore zones were mined on this lease, M bed, G-H beds, and E and Chester Beds. The M bed, which occurred about 200 ft below the surface, had working heights that varied from 9 to 22 ft. G-H beds were mined mainly in the south-central part to the lease. They occurred about 150 ft below the surface. Working heights were about the same as the M bed. The upper level workings, E and Chester Beds, were mined north of the mill and extend northward onto the Admiralty No. 2 mine. These workings were mined from 65 to 75 feet below the surface. The working heights varied from 10 to 37 ft and averaged about 30 ft. The depth to top mine workings at this location varies from 27 to 60 feet.

In the mid 1950s, American Zinc, Lead, and Smelting Company were operating this lease when some of the upper level workings caved to the surface. They built a dike around the north, east, and west sides of these workings to keep Lytle Creek from flooding the mine. EPA built the dike on the south end of the collapse to prevent mine water within the collapse from flowing into the old Lytle Creek drainage. However, their dike was eventually breached when mine water overflowed the berm.

In 1981, this area was full of water which obscured these cave-ins. The drought of 2005-2006 has caused the water table to lower about 12 feet in this area. At least 6 collapse features associated with the upper level workings are now exposed (Fig. 33). At least one of these collapses is thought to be new. This is an excellent example of a mine-roof failure that starts in the mine and propagates towards the surface to produce a cave in.

The most common collapses found in the Picher Field are associated with shafts. Unlike mine-roof failures, the collapse starts at the surface and extends downward. In 1981, there was a 10-ft circular collapse associated with shaft no. 64 (Fig 34). The water level was 8.5 ft from the surface. This shaft was filled by EPA in 1984-1986. In late 2005, this shaft recollapsed. The collapse had 25 x 10 ft rectangular shape and was 5 ft deep in January, 2006 (Fig. 35). In mid March, 2006, a large concrete slab adjacent to the collapse, 20- x 20- x 7-ft thick, rotated into the collapse.

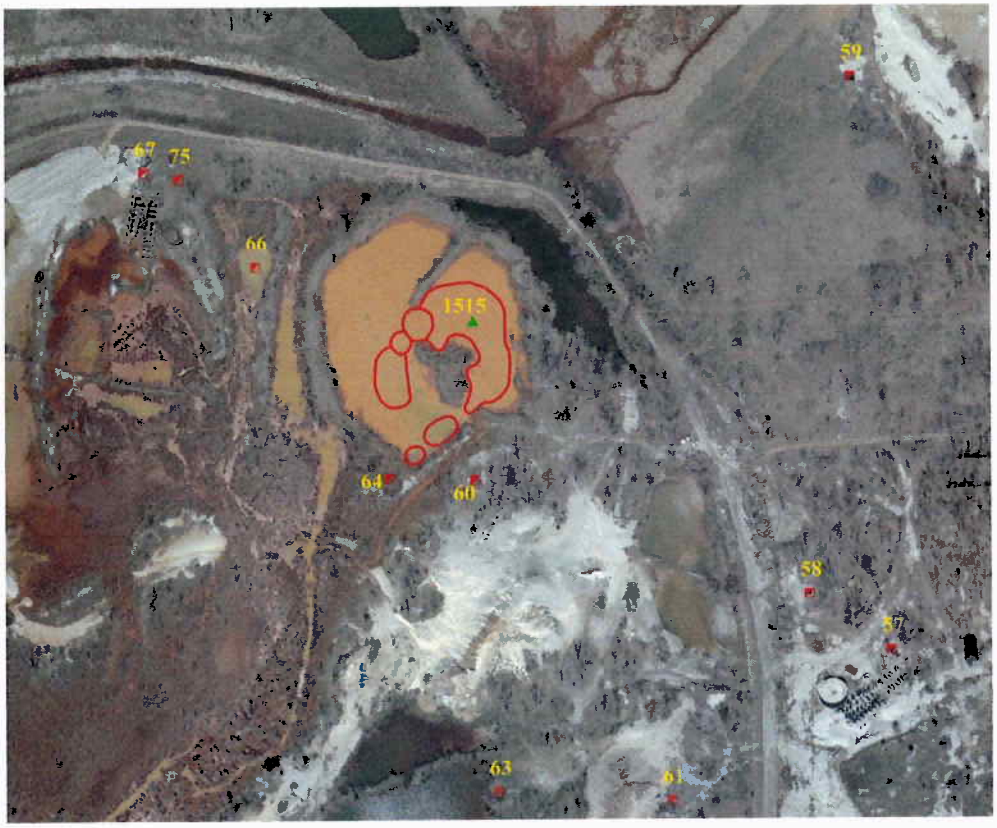

Fig. 33. Field shaft (no. 64) and mill shaft (no. 60) for the Admiralty No. 1 Mine and collapses associated with mine roof failures outlined in red north of the mill.

Fig. 34. 10-ft semi-circular collapse associated with shaft no. 64 in 1981; filled by EPA 1984-1986.

Fig 35. In late 2005, this shaft recollapsed. The collapse had 25 x 10 ft rectangular shape and was 5 ft deep in January, 2006. Photograph was taken March 4, 2006. On the left, people are standing on a 20- x 20- x 7-ft thick concrete slab that had rotated into the collapse by March 27, 2006.

STOP 3B. BOULDER PILES

Boulder Piles were created at or near most mill shafts (Fig. 36). Ore was placed in ½- to ¾-ton buckets called cans and hoisted to the surface. The ore was passed over a screen usually made out of rails before entering a hopper located next to the derrick. A man used a sledge hammer to break down any oversized rock that remained on the screen. Rock that couldn't be broken and/or barren was tramed away from the derrick to a near by rock pile. These boulder piles are excellent places to find mineral specimens and find examples of structurally deformed Boone Formation. The ore consistsed of sphalerite, galena, dolomite, and jasperoid. Accessory metallic minerals incluced chalcopyrite, enargite, luzonite, marcasite, and pyrite. Considerable amounts of calcite and some quartz and barite occur in the ore.

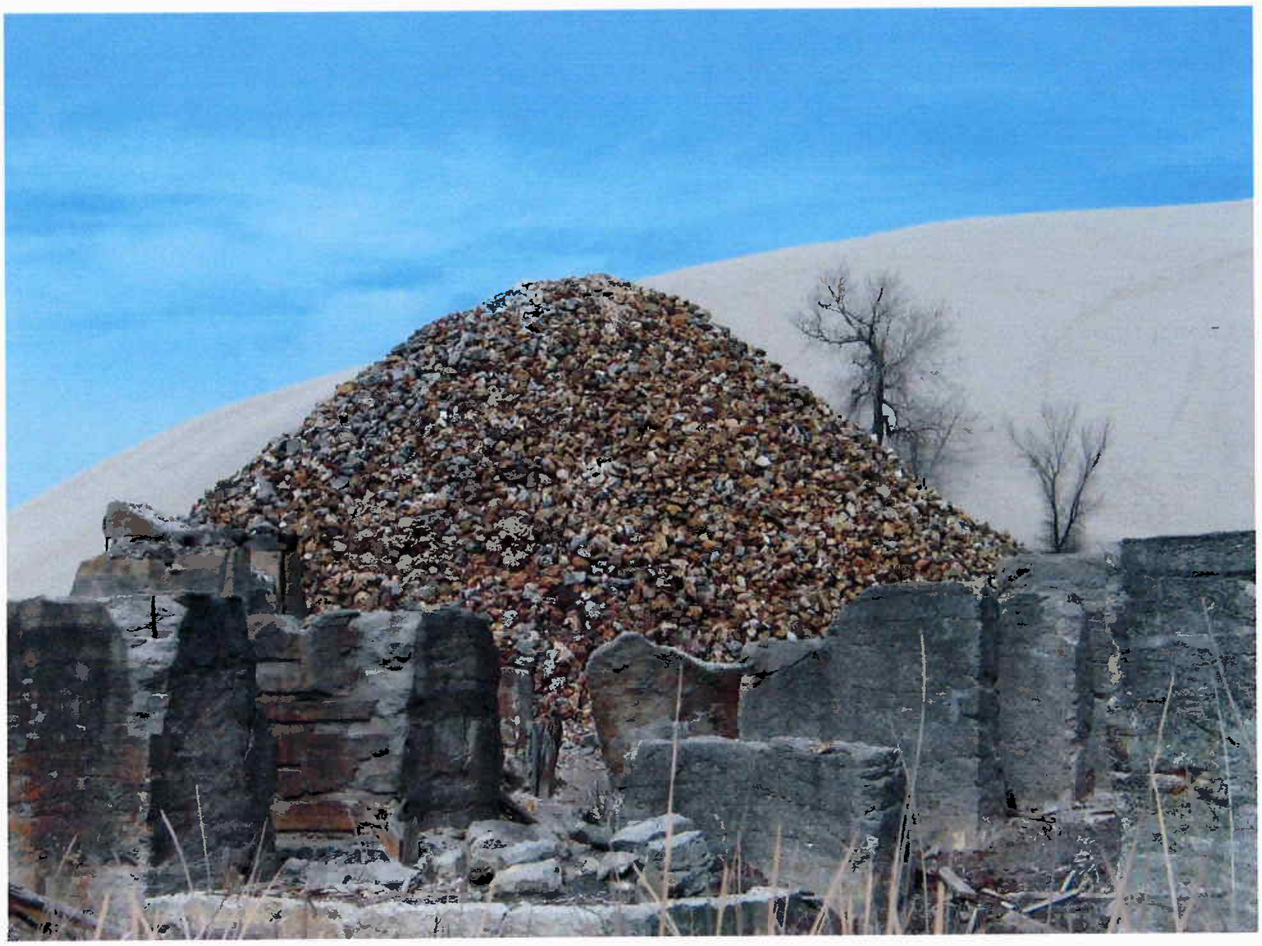

Fig. 36. Example of a boulder pile near the New Chicago No. 2 mill (T29N, R23E, sec. 28).

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Tri-State Mining District/Picher Field Timelines

Ore deposits near Joplin discovered about 1848.

Southwestern Missouri became one of the early battlegrounds during the Civil War.

1890's-early 1900's, Peoria, Quapaw, Lincolnville, and Commerce mining camps open.

In 1914, Picher Lead Co. announced discovery of a rich ore deposit on the Crawfish Lease, near what is now Picher, Oklahoma.

1920-1929, the golden years of the district.

Mid 1920's, general adoption of flotation process by mills in the Picher Field.

1926, about 143 mills were in operation in the district.

1930, the first central mill, Bird Dog mill, was completed; 2,700 tons/day.

Early 1930s, large-capacity sump pumps were pumping more than 13 million gal/day to maintain unsaturated conditions in the mine workings.

1932, Eagle-Picher completes a central mill; initial capacity 3,600 tons/day; stepped up to 5,500 tons/day.

1940-1949, many ups and downs, with the mining industry being subjected to the governmental controls associated with Word War II.

1950-1959, marked the end of the major mining activities within the Tri-State District.

1970, the last record of significant production.

November 1979, acid-mine water began discharging from an abandoned drill hole near Commerce.

Early 1980, Governor of Oklahoma, George Nigh, formed a the Tar Creek Task Force, composed of 24 local, state, and federal agencies, to investigate the effects of acid mine drainage on the areas's surface and ground water supplies.

July 1981, EPA proposes to add the Site to the Superfund National Priorities List (NPL).

On September 8, 1983 the Site was listed on the NPL.

1984-1986, dikes were built to divert surface water around collapsed mine shafts and 88 abandoned Roubidoux wells were plugged (OU1).

1995, EPA begins yard remediation activities in the five-city mining area in response to elevated blood-lead levels in children (OU2).

2000, EPA disposed of 120 deteriorating containers of lead recovering chemicals at Eagle-Picher Industries mining laboratory in Cardin.

January 26, 2000 Governor Frank Keating creates a task force to develop a comprehensive remediation plan for Tar Creek.

2003, Oklahoma plan is developed for stream restoration, maximum chat utilization, land remediation and restoration, and mine-hazard attenuation.

2003, MOU signed by EPA, DOI, and U.S. Army Corps of Engineers

2003, the Oklahoma Conservation Commission (OCC) completes a 54-acre land reclamation and restoration pilot project at McNeely Site.

2004, U.S. Army Corps of Engineers completes assessment of the Tar Creek and Spring River Watersheds.

2004, EPA initiates a chat disposal pilot project; OCC begins land restoration project near Commerce.

2004, Lead Impacted Communities Relocation Trust was formed to move children 6 years old and younger away from the Picher-Cardin area.

2006, Report to evaluate the potential for future subsidence in the Tar Creek Superfund Site in key transportation corridors and population centers was released.

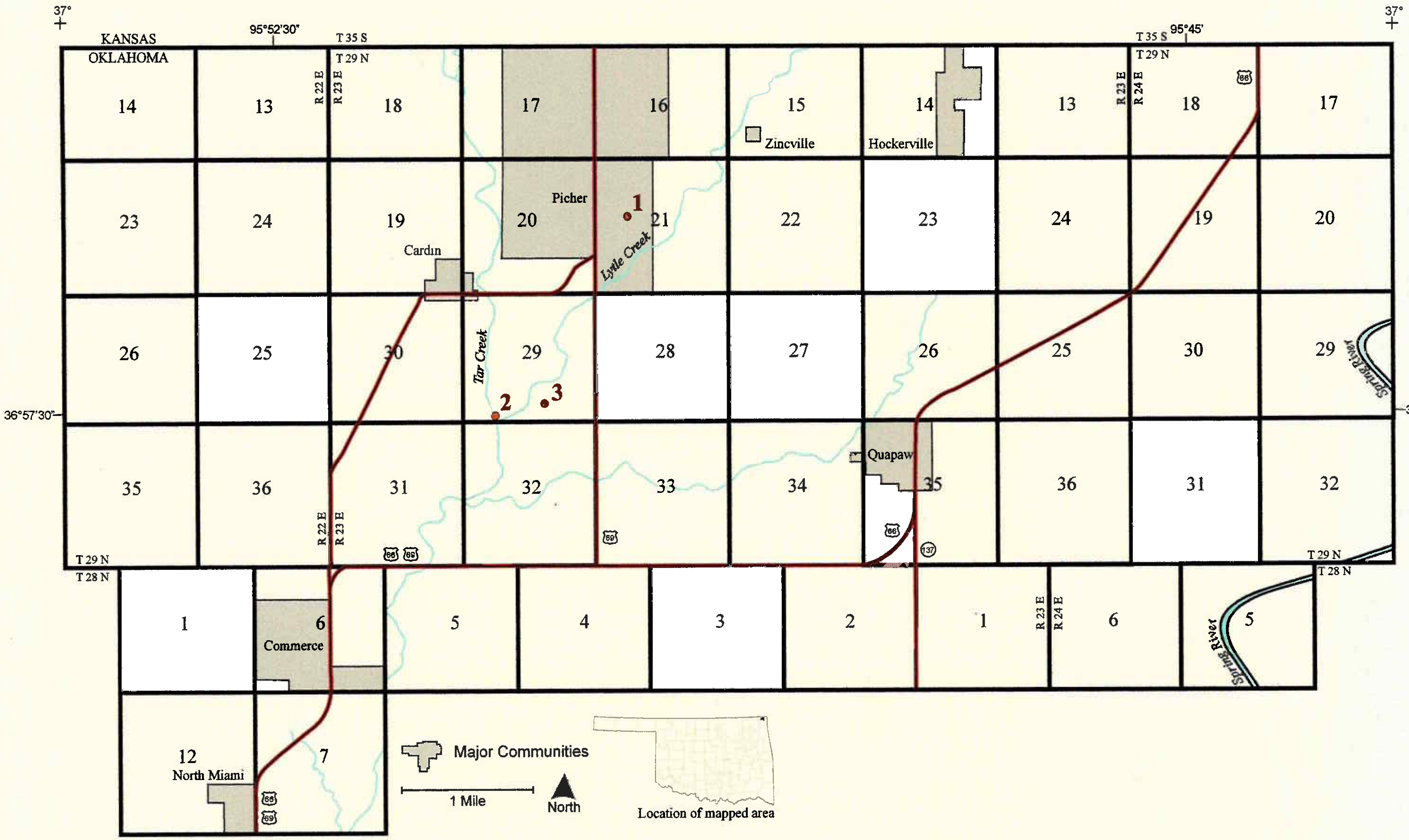

Fig. 37. Location map showing field trip stops.